*"I would have everie man write what he knowes, and no more."*
—MONTAIGNE

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## EDITORIAL

THERE is no doubt that when the Faculty of Anæsthetists instituted the examination for its Fellowship it foresaw difficulties. There is also no doubt that the Faculty, having no axe to grind but the advancement and prestige of anæsthesia, was determined to do everything possible to overcome these difficulties. The Fellowship by examination is to take the place of the Conjoint Diploma in Anæsthetics as the examination for intending Consultants in anæsthesia.

Two main reasons have made necessary this change. The first and immediate impetus to the change was that the two-part D.A. was of a standard considerably higher than the other Conjoint Diplomata, and therefore it was presumably out of line with the policy of the Conjoint body. Secondly, it was obviously desirable that the Faculty of Anæsthetists, the real academic authority in the subject, should provide and organize the qualifying examination for Consultant Anæsthetists.

The main difficulty foreseen was that the new examination would create a situation in which young, newly qualified anæsthetists might *appear* better qualified than their senior brethren, their teachers, and possibly those who would be sitting as advisers on Appointment

Committees before which these aspirants might appear. To overcome this the Faculty is awarding its highest honour to those anæsthetists whose position and standing make them worthy recipients. In this the Faculty is following the precedent of its College. When the Fellowship of the Royal College of Surgeons was instituted under the 1843 Charter, the College was empowered to create initially from 250 to 300 Fellows in three months, and a further number of Fellows within one year. These Fellowships were awarded on the recommendation of a Sub-Committee set up for the purpose. There is no evidence that there was any public invitation to Members to apply for Fellowships. There was nothing to stop Members applying—some did, and some were successful; they would probably have been included in the list anyway.

In our last issue we published a letter from Dr. Galley expressing concern at the possibility of injustice through some persons being overlooked when drawing up a list of those who are to be offered the Fellowship. Clearly all are agreed with the widely known policy of the Faculty to award the Fellowship to those who have been successful in obtaining both parts of the D.A. It is in regard to the election of " a certain undefined number of those who took the D.A. under the old regulations " that Dr. Galley fears invidious distinction and oversight, to avoid which he suggests that a questionnaire should be sent to all anæsthetists and thus provide them with an opportunity of giving relevant information to the Committee responsible for this election. The Dean of the Faculty wrote a reply to reassure Dr. Galley that the Faculty had considered the point raised, together with many others, and he hoped that correspondence in the journals on this matter would not be pursued until the over-all picture could be seen. We have received other letters supporting Dr. Galley's thesis which add

nothing original, and for the moment we intend to respect the Dean's wishes and withhold their publication.

Several points, however, occur to us. It is the unquestionable right of the Faculty to elect to their Fellowship only those whom they may wish. The controversy regards only the best method of affording to the Advisory Committee concerned the relevant information.

It is doubtful whether any person applying for a Fellowship and being turned down would feel any happier than one who, without applying, did not receive the diploma. Two courses of action lie open to the latter individual, which are closed to the former. He may either write directly to the Faculty drawing attention to himself as a worthy recipient. There is nothing to stop him doing this as there was nothing to stop original Members of the College applying for the Fellowship. Alternatively he may write to a Fellow who is a member of the Board of Faculty urging that his case be considered.

A questionnaire, while it might be of some help to the Committee, would, in any case, have to be checked for accuracy, and those concerned would have very little, if any, less work than they have at present. It is no secret that the Board of Faculty has been arduously (and the word is deliberately chosen) engaged with this problem for months, and is likely to continue to be so engaged for some time to come.

This is an independent journal owing allegiance to no authority or association. If there is real injustice established, all the publicity possible will be given in a constructive effort to right the position. At the moment no injustice is apparent.

The practice of encouraging Registrars to contribute to meetings of local Anæsthetic Societies is to be recom-

mended. The Scottish Society has instituted the admirable plan of awarding an annual prize to the best Registrar contribution. Perhaps it would be a further incentive if such essays were to be published, and certainly we have no hesitation in publishing the contribution of this year's prizewinner, Dr. Preston. A point with which he has not dealt, perhaps because he regards it more in the realm of the physician than of the anæsthetist, is the importance of pre-operative assessment in the prognosis of these patients. It is, therefore, particularly apt that an annotation on this subject should accompany this essay.

A difficult and involved problem has been exercising the Editorial Board. What is to be the policy of this journal regarding abstracts? It seems that this field of activity is so well covered that any further effort on our part to supply a service for readers would only be repeating work and wasting valuable space. There are available to anæsthetists in this country abstracts from current literature in *Excerpta Medica*, and, of course, the Anesthesia Abstracts prepared by the Mayo Clinic under the Editorship of Dr. John Lundy. In addition, there are comprehensive surveys given in *Anæsthesia*, *Anesthesiology*, and *Current Researches in Anesthesia and Analgesia*. The latter journal and *Anæsthesia* also prepare a current list of literature likely to be of interest to anæsthetists. This must surely provide for all our needs, and it would seem that, if this type of activity is extended any further, there is danger of a *reductio ad absurdum* in a journal abstracting its own article. We have therefore decided against the initiation of an abstracting service. We are, however, intending to provide from time to time not only review articles of the type prepared by Dr. Woolmer for this issue, but also annotations of current problems of interest. The

first of these are appearing in this issue and concern refrigeration and hibernation, and the assessment of patients for valvotomy.

The Editors invite readers of the JOURNAL to submit such annotations. They should be of 500 to 1,000 words.

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# THE EFFECTS OF HEXAMETHONIUM IODIDE ON THE ELECTROCARDIOGRAPH IN ANÆSTHETIZED SUBJECTS

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ELECTROCARDIOGRAPHIC recordings during and after the use of hexamethonium have already been reported. Thus, James (1953) and his co-workers have taken electrocardiographs before, during and after hypotension produced by hexamethonium; they found no suggestion of myocardial ischaemia. Wyman (1953) found frequent but transient post-operative T wave changes after the use of hexamethonium.

The present investigations were carried out to determine if any immediate changes in cardiac function could be demonstrated electrocardiographically following the intravenous injection of hexamethonium iodide.

## SUBJECTS

Forty patients were studied, all of whom were undergoing ear, nose and throat operations. All were fit and healthy apart from their local condition and their ages ranged from fourteen to sixty-eight years; a detailed analysis is given in Table I.

## TECHNIQUE

The premedication in patients under eighteen and over sixty years was morphia gr. 1/6 (10 mg.), atropine gr. 1/100 (0.65 mg.), the remainder received papaveretum gr. 1/3

TABLE I

*Age Distribution of Patients*

| Decade | No. of patients |
|---|---|
| 11–20 | 11 |
| 21–30 | 14 |
| 31–40 | 6 |
| 41–50 | 4 |
| 51–60 | 3 |
| 61–70 | 2 |
| Total | 40 |

(20 mg.), scopolamine gr. 1/150 (0.45 mg.). On the arrival of the patient in the anæsthetic room an electrocardiograph record was made using the standard leads in order to give the normal (pre-operative) resting tracing and, at the same time, the resting blood pressure was determined by auscultation.

In the operating theatre the patient was anæsthetized, the technique used depending on the operation to be performed. Intubation was carried out in all cases the tube being well lubricated with 10 per cent cincochaine cream. When it was quite certain that the patient had " settled " under the anæsthetic another electrocardiograph was taken and once more the blood pressure was determined. The table was then tilted to 20 degrees of anti-Trendelenburg tilt, and further electrocardiographic and blood pressure records were made.

The requisite dose (see below) of hexamethonium iodide was now given via a Gordh needle into one of the forearm veins, the injection being carried out rapidly. Immediately the injection was completed the electrocardiographic recordings were recommenced and the tracing was continued until auscultation showed that the blood pressure was no longer falling rapidly. Katz (1946) has pointed out the need to standardize the electrocardiograph for every

new position the patient adopts; it will be seen that in this work the electrocardiograph taken after the injection of hexamethonium iodide can be compared with that taken under the anæsthetic alone, after tilting, and with the normal resting record. Leads 1 and 2 were each used for the theatre tracings in twenty cases. The interval between the time when the patient was tilted and the beginning of the post-hexamethonium tracing varied a little in different cases, but was about three minutes.

The electrocardiogram was controlled by the same operator throughout this investigation. All the anæsthetics were administered, and the blood pressure taken, by one of the writers (M.S.).

*Anæsthetic*

As has been stated above, the type of anæsthetic depended primarily on the nature of the operative procedure about to be performed. In fourteen cases the anæsthetic used was nitrous oxide-oxygen-ether administered by semi-open circuit using a Boyle's machine. The other twenty-six patients were induced with 8–10 ml. of 5 per cent sodium thiopentone solution, and the cords were then sprayed under direct vision with 2 per cent lignocaine solution before intubation. Anæsthesia was maintained by nitrous oxide-oxygen (5 litres: 2 litres) in a semi-open circuit, with thiopentone supplements. No other anæsthetic agents were used until after the electrocardiographic recordings had been completed. Anoxia was, of course, avoided throughout.

*Hexamethonium*

The dose of hexamethonium iodide administered in each case was based on a consideration of:

(1) The blood pressure change produced by tilting and

by the thiopentone (in those patients who received this drug).

(2) The age and pre-operative blood pressure of the patient.

Twenty-three patients received 150 mg. of hexamethonium iodide, eleven were given 100 mg., while six received a dose of 50 mg.

*Pre-operative Electrocardiographs*

All the tracings taken in the anæsthetic room prior to anæsthesia were normal, but in twelve cases there was an arrhythmia present and, of these, three showed premature ventricular beats, two had a sinus tachycardia and seven exhibited sinus arrhythmia.

## RESULTS

The main changes which are noticed on reading the experimental electrocardiographs are an alteration in the rate, and changes in the P wave and P-R interval.

*Alteration in Rate*

Twenty-four cases (60 per cent) showed a change in heart rate after hexamethonium. Table II gives an analysis of these cases. It must be remembered that the tracing was commenced immediately after the completion of the injection of hexamethonium and was continued for an average of ninety seconds.

TABLE II
*Analysis of rate changes*

| Change in rate | Type | No. of patients |
|---|---|---|
| Acceleration | Immediate | 5 |
| | Delayed* | 9 |
| Deceleration | Immediate | 8 |
| | Delayed* | 2 |

* The change in rate was not present at the commencement of the post-hexamethonium tracing but appeared after a number of seconds; in several cases the change in rate gradually became more marked.

*Alteration in P-R Interval*

The post-hexamethonium tracings frequently showed a diminution in the P-R interval which varied from a slight reduction to a complete absence, when the P wave is found buried in the up-stroke of R and then disappears. In 14 cases (35 per cent) the administration of hexamethonium caused this complete but transient disappearance of the P wave, and figure 1 shows a tracing which is typical of these cases. The disappearance of the P wave bore no apparent relationship to the dose of hexamethonium given, to the degree of hypotension produced or to the nature of the anæsthetic administered in the particular case.

Alteration of the P wave has also been seen not only after hexamethonium injection but in six of the tracings after tilting. Of these six, four showed a complete absence of the P wave (fig. 2) whilst in two the P wave became less well defined. Tilting did not produce a change in the P wave in any patient who did not show subsequently a disappearance of the P wave after hexamethonium. However, in one case the P wave became poorly defined in the post-anæsthetic tracing, but was quite normal in the records obtained after tilt and after hexamethonium injection.

In order to illustrate the changes in rhythm that may occur under anæsthesia and after tilting we include figure 3, which is the electrocardiograph of a girl of 24 years who had recently recovered from sub-acute bacterial endocarditis. There was no evidence of cardiac enlargement or stress, and she had signs of mitral valvular disease. She was anæsthetized with nitrous oxide-oxygen-ether, tilted and given 150 mg. of hexamethonium iodide intravenously. There was no immediate fall in blood pressure. The electrocardiograph showed that a nodal tachycardia developed under anæsthesia, and this changed to auricular

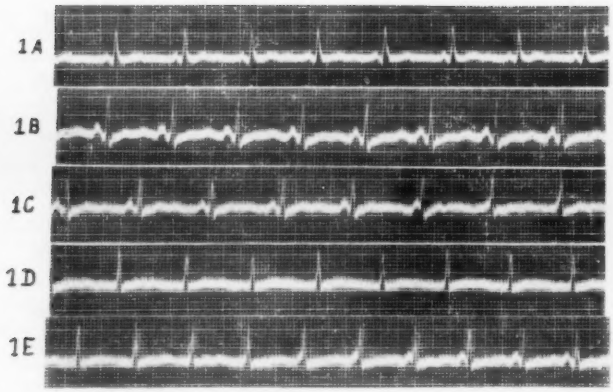


FIG. 1

A. H., male, aged 34

(a) Record under anæsthesia. Normal rhythm (lead 1).
(b) Bed tilted. Normal rhythm (lead 2).
(c), (d), (e). Hexamethonium iodide injected. Narrowing of PR interval well shown, followed by disappearance and then return of P waves (lead 2).

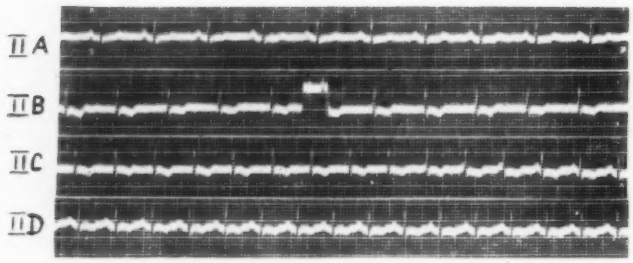


FIG. 2

G. D., female, aged 30 (lead 2 throughout).

(a) Record under anæsthesia. Normal rhythm.
(b) P waves absent after tilting (standardization deflection in middle of record.
(c), (d) Hexamethonium iodide injected. P waves return.

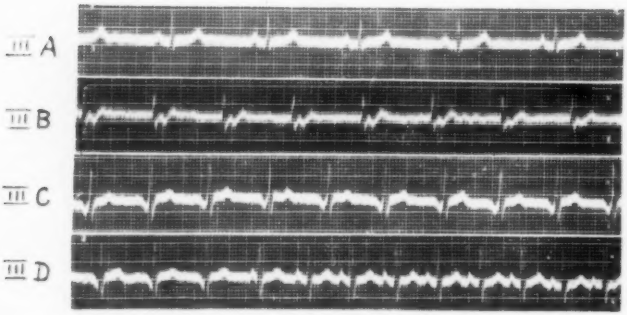


FIG. 3

S. R., female, aged 24 (lead 2 throughout).

(a) Normal rhythm. Resting record.
(b) Nodal tachycardia under anæsthesia.
(c) Bed tilted. Auricular tachycardia.
(d) Hexamethonium iodide injected. Sinus rhythm returns after 9 seconds.

tachycardia after tilting. The P waves returned to normal nine seconds after hexamethonium was administered.

*Blood Pressure Changes*

The alteration in blood pressure produced by hexamethonium iodide in the tilted and anæsthetized subject showed considerable variation in the 40 patients studied here. Four cases showed a rise in diastolic pressure of between 15 and 20 per cent, and in a further 2 cases the diastolic pressure did not change. In 3 patients the diastolic pressure became unrecordable. In the remaining 31 subjects there was a fall ranging from 8 to 50 per cent of the pre-hexamethonium diastolic level, the average fall being 29 per cent.

## DISCUSSION

Of the electrocardiographic changes which we have recorded after the intravenous administration of hexamethonium iodide none can be considered specific to this drug. The alteration in rate has been observed without the injection of hexamethonium and is not related to the fall in blood pressure consequent upon the administration of this drug. The disappearance of the P wave and shortening of the P-R interval have been seen not only following the injection of hexamethonium but also after tilting of the anæsthetized subject alone. Such tilting of the patient under anæsthesia may alter the vasomotor tone, and this could account for the P wave changes. The diminution in the P-R interval was not constantly seen after hexamethonium injection and, moreover, it was frequently produced by tilting alone. It is not related to the subsequent fall in blood-pressure or to tachycardia and is presumably a vagal depressant effect.

Despite the large dosage used the changes in P wave and in P-R interval noted in this investigation were, in every

case, short lived. All the records indicate that no structural myocardial changes occur consequent upon the injection of hexamethonium iodide.


## SUMMARY

(1) In 40 subjects electrocardiographic recordings were taken (*a*) in the resting state before anæsthesia, (*b*) after induction of anæsthesia, (*c*) after the patient had been placed in a position of 20 degrees reverse Trendelenberg tilt, (*d*) after the intravenous injection of hexamethonium iodide.

(2) The tracings after hexamethonium injection in some cases showed a change in rate and a transient alteration in the P wave and P-R interval. Similar changes were seen in some cases after tilting alone.

(3) There was no electrocardiographic evidence of structural myocardial change consequent upon the use of hexamethonium iodide.



## ACKNOWLEDGMENTS

We are indebted to Mr. L. D. Mercer for permission to carry out this work on his patients, to Mr. F. R. Martinson who operated on many of the patients for his co-operation, and to our electrocardiographer, Miss Chapman, for her technical assistance. Our thanks are also due to Mr. Hodkinson of the Department of Clinical Photography, Skin Hospital, Manchester, for the electrocardiographic reproductions.


## REFERENCES


James, A., Coulter, R. L., and Saunders, J. W. (1953). *Lancet*, **1**, 412.

Katz, L. N. (1946). " Electrocardiography ", 1st edition. London: Kimpton.

Wyman, J. B. (1953). Hunterian Lecture. Royal College of Surgeons.

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# A METHOD FOR DETERMINING THE DURATION OF THIOPENTONE NARCOSIS IN THE DOG

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MOST of the experimental work on the duration of thiopentone narcosis under varying conditions has been done on small animals, e.g. rabbits or guinea pigs. The return of the righting reflex, when the animal assumes its normal position, has been taken as the end point in most of the recorded experiments on dogs. This end point is reported in most instances to have been very definite and often appeared very suddenly (Paulson, Lundy and Essex, 1949). A method of determining the duration of thiopentone narcosis in the dog is described in this paper; it is compared with other possible methods, and the significance of any results obtained with it are discussed.

## METHOD

The maximal tolerated dose of thiopentone in the dog is between 35 mg./kg. (Werner and Pratt, 1936) and 45 mg./kg. (Gruhitz, Dox, Rowe and Dodd, 1937), while the minimal anæsthetic dose is about 10 mg./kg. (Gruhitz et al., 1937). Wright (1947) recommends doses of between 20 and 30 mg./kg. for anæsthesia lasting about 5 minutes. In practice I have found that doses of between 15 and 25 mg./kg. have proved very satisfactory. The animal remains anæsthetized long enough to enable different signs to be observed, yet ultimate recovery is never so long

delayed as to prevent observations on a number of dogs from being carried out on the same day.

A well-marked excitement stage occurs with thiopentone in the dog if the rate of injection is too slow. This may result in dislodgement of the needle from the vein, reinsertion being practically impossible until the animal quietens. It is essential in any experiments designed to measure the duration of narcosis that the rate of injection of the drug be constant. This can easily be achieved by using a "closed vein" technique and a concentrated (10 per cent) solution of thiopentone. Duration of anæsthesia is then measured from the time when the tourniquet on the limb is released. Injection into the jugular vein (Gruhitz et al., 1937) cannot be carried out with this technique, but in a personal series of about 200 injections it was found that dogs weighing 9–15 kg. had sufficiently large veins in the forelegs to permit numerous injections to be made. Wright (1947) has pointed out that the anæsthesia resulting from rapid injection of thiopentone is alarmingly abrupt in onset and followed by considerable shock. This has not been observed using doses of 15–25 mg./kg.; there has always been a brief period of apnoea, but even with 30 mg./kg. this did not last for more than one minute.

During this series of cases it was observed that in animals, in whom, for any reason, the thiopentone was given in divided doses, the duration of narcosis was much more prolonged than if it had been given in one injection. Even a pause of 10 seconds, to enable a needle to be reinserted into a vein, upset the readings. This is difficult to explain save on the grounds of acute tolerance to the drug. The central nervous system may respond to the initial peak concentration of the drug, and the plasma level at which awakening occurs may be related to this concentration (Brodie, 1952). Whatever may be the explanation, any

trouble during injection is an indication that the experiment should be abandoned for a further 48 hours.

In spite of observations to the contrary (Adams, 1944), acquired tolerance to thiopentone has been observed in the dog. Thrice weekly injection of the same dose was found to reduce significantly the duration of narcosis by the end of the third week, but the tolerance disappeared after a rest for one week. In practice twice weekly injections for 3 weeks out of 4 had no significant effect on the duration of narcosis. Tolerance to one barbiturate will result in tolerance to others (Green and Koppanyi, 1944). This has been observed in the case of thiopentone, hexobarbitone and thialbarbitone. However, cumulative effects of thiopentone became manifest when injections were repeated at intervals of 36 hours or less (Dundee, 1953). To be certain of avoiding this an interval of not less than 48 hours should elapse between successive injections of the drug.

A series of well defined end points can be observed in the dog as follows.

1. *Return of the corneal reflex.* This reflex does not disappear until about 20 seconds after the tourniquet is released, and care must be taken lest these two phases be confused.
2. *Spontaneous return of blinking.*
3. *Head raising.*
4. *Sitting up*: defined as the point where the dog raises its shoulders from the ground.
5. *Standing*: defined as the moment when the animal first stands unsupported on all four limbs.

For an accurate comparison of these on different occasions the surroundings of the animals should be the same at each injection, e.g. noises may cause the head to be raised sooner, a slippery floor may prolong the time of the last observation, etc.

The method advocated uses the average of the times of appearance of the above 5 signs (measured from release of the tourniquet) as the duration of anæsthesia.

## RESULTS

A statistical analysis of figures obtained from 16 injections of 16.3 mg./kg. thiopentone in one dog are shown in table I. Attention was paid to all the points mentioned in regard to the injection, control of surroundings, etc. The

TABLE I

*Showing average results obtained from 16 observations on one dog using various end points, following 16.3 mg. thiopentone per kg. body weight.*

| End point | Average time (secs.) | Range (secs.) | Standard deviation | Coefficient of variation |
|---|---|---|---|---|
| Return of corneal reflex | 50.3 | 20–105 | 22 | 43.7 |
| Blinking ... ... ... | 125 | 40–285 | 39.5 | 31.6 |
| Head raising ... .. | 260 | 140–390 | 55.8 | 21.4 |
| Sitting ... ... ... | 331 | 240–470 | 76.5 | 23.1 |
| Standing ... ... ... | 516 | 420–720 | 93.5 | 18.1 |
| Average of above ... | 259 | 185–332 | 40.3 | 15.5 |

times taken for the return of the corneal reflex and appearance of blinking are too variable to be of any value. The other three end points, although much less variable, do not give results as constant as are obtained using the average time of all five. There is very little to choose between this and using the return of standing as the sole end point, but it would seem to reflect better changes in the course of anæsthesia, rather than showing the time of ultimate recovery.

Table II shows results obtained with 4–6 injections in 9 other dogs using this method and two comparable results for thialbarbitone and hexobarbitone. Even with only 4 injections the coefficient of variation did not exceed 12.4.

It is necessary to establish the "normal sleeping time" for a fixed dose of thiopentone before subjecting a dog to

TABLE II

*Showing results obtained in 11 series of experiments using method referred to in text to determine duration of barbiturate narcosis, comprising 4–6 administrations of each dose*

| Dose of thiopentone mg./kg. | No. of observations | Average duration of narcosis (secs.) | Range | Standard deviation | Coefficient of variation |
|---|---|---|---|---|---|
| 14.0 | 6 | 310 | 268–350 | 36.0 | 11.6 |
| 15.8 | 5 | 398 | 360–451 | 44.0 | 11.1 |
| 15.8 | 5 | 475 | 414–582 | 46.3 | 9.7 |
| 16.0 | 5 | 652 | 607–750 | 58.3 | 8.9 |
| 17.0 | 5 | 453 | 426–484 | 22.4 | 4.9 |
| 21.0 | 6 | 526 | 462–593 | 58.2 | 11.1 |
| 22.0 | 4 | 618 | 588–660 | 26.5 | 4.8 |
| 27.0 | 4 | 991 | 946–1050 | 45.7 | 4.6 |
| 30.0 | 4 | 2215 | 2080–2758 | 275 | 12.4 |
| 26.0(K) | 5 | 191 | 171–233 | 21.5 | 11.2 |
| 36.2(E) | 4 | 1014 | 920–1092 | 100 | 9.8 |

K=Thialbarbiturate (Kemithal) used.
E=Hexobarbitone (Evipan) used.

any procedure which will alter its response to thiopentone. Tables I and II show that, using the method described, this can be accomplished by 4–6 injections of the same dose of the drug. The duration of narcosis obtained following any one injection should be well within the range of "average ± 20 per cent". For the duration of narcosis under different conditions to differ significantly from the normal, an allowance must be made for this variation. Preliminary results indicate that this method is equally applicable to any of the other ultra-short-acting barbiturates in common use.

As in humans, the duration of anæsthesia produced by thiopentone in the dog is not constant in the same animal from day to day. Tables I and II indicate that even more variable are the results obtained with the same dose in different dogs. There would appear to be no grounds for comparing the duration of narcosis in one dog with that of

another dog who received the same dose per kilogram body weight.

SUMMARY

1. The difficulties encountered in assessing the duration of thiopentone narcosis in the dog are discussed.

2. A method is described using the average times required for return of 5 different end points.

3. The significance of any results obtained using this method are discussed.

ACKNOWLEDGEMENTS

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REFERENCES

Adams, R. C. (1944). *Intravenous Anæsthesia*, London: Hoeber.
Brodie, B. B. (1952). *Fed. Proc.*, **11**, 632.
Dundee, J. W. (1953). Paper read to Yorkshire Society of Anæsthetists, 1st July
Green, M. W., and Koppanyi, T. (1944). *Anesthesiology*, **5**, 329.
Gruhitz, O. M., Dox, A. W., Rowe, L. M., and Dodd, M. C. (1937). *J. Pharmacol.*, **60**, 125.
Paulson, J. A., Lundy, J. S., and Essex, H. E. (1937). *Anesthesiology*, **10**, 387.
Werner, H. W., and Pratt, T. W. (1936). *J. Pharmacol.*, **59**, 149.
Wright, J. G. (1947). *Veterinary Anæsthesia*, 2nd edition. London: Baillière, Tindall & Cox.

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# A MODIFICATION OF EXTON'S METHOD FOR BLOOD OXYGEN CONTENT

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The convenience and speed of the method for estimating the oxygen content of blood which was described by Exton et al. (1945) has been increased by modifications which permit the whole procedure to be carried out in a special syringe.

The reagents used are identical with those required by Exton et al. and the original article should be consulted for their preparation.

The special syringe comprises a 1 ml. tuberculin syringe fused on to a length of 0.3/0.5 capillary tube (fig. 1). A mark on the capillary tube is made such that the capillary will contain 0.1 ml. of blood between its entry and the mark. The plunger of the syringe should be controlled by a spring-clip.

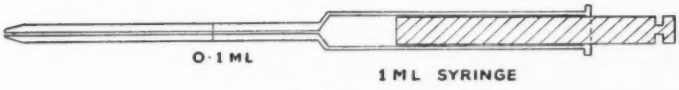


Fig. 1

*Procedure*. Fill the syringe and capillary with borax solution, expel all air bubbles and then expel the borax solution until the plunger of the syringe stands at the 0.2 ml. mark. Draw in a small amount of mercury (about 0.01–0.02 ml.).

Draw up 0.1 ml. of ferrous sulphate solution, so that the outer edge of the mercury bead stands at the mark on the capillary. To prevent any entry of air, part of the first

mercury bead can be ejected into the ferrous sulphate solution. Follow the ferrous sulphate with a second mercury bead.

Draw in blood carefully so that the outer edge of the mercury bead stands exactly on the 0.1 ml. mark on the capillary. This is the only measurement which needs to be made with great precision. Immediately follow the blood by drawing in a mercury bead.

If the blood sample is contained in a syringe, a short length of elastic tube can be used to unite the blood syringe and the capillary tube for filling in the usual way. Finally, draw up further borax solution until the plunger of the syringe stands at the 0.6 ml. mark.

The mercury beads will now have found their way into the syringe and can be used for mixing its contents. Leave the syringe for two minutes. There is no need to cap the outer end of the capillary since the active reagents are protected from atmospheric air by several cms. of aerated borax solution.

Place 2 ml. of sulphosalicylic acid in a tube calibrated to 10 ml. Draw some of this solution into a syringe and eject immediately into the same tube. Now repeatedly draw up distilled water into the syringe and eject into the 10 ml. tube until its mark is reached. In this way the syringe is rinsed and washed clean ready for the next estimation and the dilution is performed conveniently.

The contents of the 10 ml. tube are then filtered as described in the original method and the clear filtrate estimated in the cuvette of a photocolorimeter.

Blank estimations and calibrations are performed in the manner described in the original article.

REFERENCE

Exton, W. G., Schotter, F., Korman, S., and Rose, A. R. (1945). *J. Lab. clin. Med.*, **30**, 84.

*Brit. J. Anæsth.* (1953), **25**, 299

# ANÆSTHESIA FOR MITRAL VALVOTOMY*

By FRANK S. PRESTON

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THE object of this paper is to discuss the use of nitrous oxide supplemented with pethidine in the operation of mitral valvotomy for the relief of mitral stenosis.

Direct surgery of the stenosed mitral valve is no new conception. Indeed, as far back as the year 1902, Brunton put forward the plea for surgical disruption of the stenosed valve, but he met with such determined opposition that his idea was allowed to lapse into obscurity. It was H. S. Souttar of the London Hospital who, in 1925, performed the first mitral valvotomy on a girl of 15 years of age. Anæsthesia in this case was punctuated by a series of crises, the pulse rate rising at times to 150 per minute and the heart being grossly irregular on handling. Despite an immediate post-operative systolic blood pressure of 60 mm.Hg, the patient made an uneventful recovery. Pribram, in Germany, reported one successful case in 1928.

It is to Bailey of Philadelphia that we owe the modern operation of mitral commissurotomy, that is the splitting of the stenosed valve at either commissure. Following the publication of his work in 1949 many surgeons have attempted the operation. Baker, Brock and Campbell (1950), Brock (1950), in London; Murray (1950), in Montreal and Smithy, Boone and Stallworth (1950) in Baltimore, have published several papers on this operation.

* This paper, which was read to the Scottish Society of Anæsthetists at Dunblane on April 25, 1953, has been awarded the Registrars' Prize for 1953.

At this junction I should like to consider for a few moments the patient with mitral stenosis. Mitral stenosis follows, often after a long period, rheumatic infection of the heart. Although this may have occurred in youth or early adult life, the rheumatic infection may have passed unnoticed. In fact many patients with severe stenosis have no previous history of rheumatic disease.

Dyspnoea is one of the earliest symptoms of mitral stenosis and this is noticed at first only after fairly severe exercise. However, the onset of dyspnoea occurs earlier as the stenosis becomes more severe.

In figure 1 I have plotted, diagrammatically, exercise tolerance against time in years, the years across which the disease pursues its relentless path. Exercise tolerance is adjudged as the point at which dyspnoea results in the performance of standard graded exercises, such as walking on the level, or up a series of steps. It is surprising how little a patient with severe stenosis will be able to perform. It will be seen from the figure that as the disease progresses so the exercise tolerance diminishes.

The left auricle dilates and hypertrophies and, due to damming back of blood in the pulmonary system, the right ventricle in turn becomes dilated and hypertrophied with a consequent rise in the pulmonary artery pressures. This in turn results in chronic cough with a marked tendency to attacks of pulmonary oedema. Indeed, in the later stages of the disease, attacks of pulmonary oedema may be frequent and may result in right-sided cardiac failure and death.

Chronic venous congestion also becomes apparent, the systemic veins become dilated, the liver enlarged and peripheral oedema, especially of the ankles and sacral region may be seen. Cyanosis is often severe and the typical

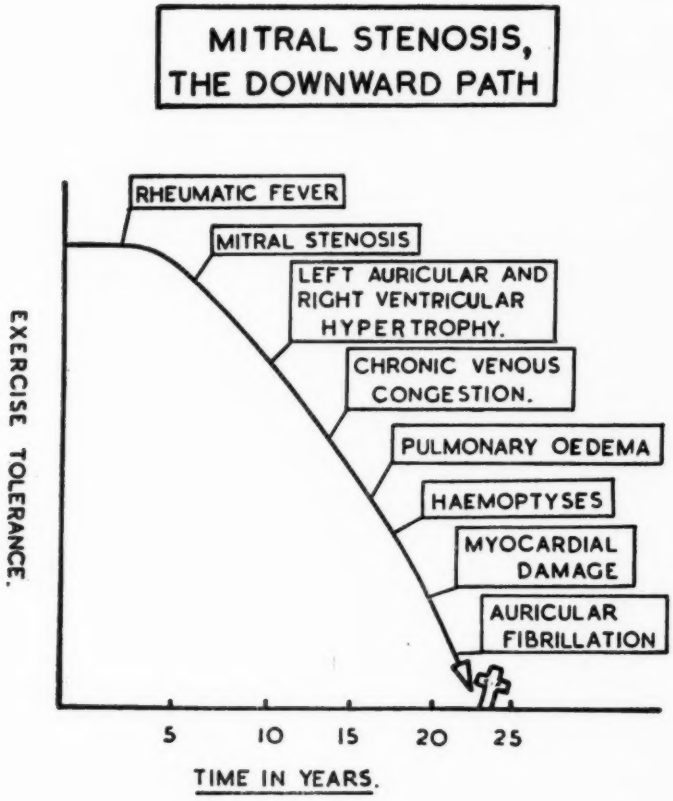


FIG. 1

Graph showing fall in exercise tolerance as the disease progresses.

mitral facies is frequently seen. Clubbing of the fingers is also a fairly common finding. Auscultation of the chest nearly always reveals moist sounds at both bases and the patient may have in addition a chronic bronchitis. Nocturnal dyspnoea is a common finding and the patient may frequently sleep in the sitting position.

In the later stages of the disease frequent small haemoptyses occur and are a further sign of a rising pulmonary artery pressure.

Sooner or later, evidence of myocardial damage will be seen electrocardiographically and auricular fibrillation and flutter are common. It is possible to perform the operation at all stages of disease, even in the case with frank auricular fibrillation. Several of the cases in this series were in fact fibrillating before, during and after valvotomy.

## THE OPERATION

Briefly the operation consists of a left thoracotomy with, usually, resection of the 4th rib. The left lung is collapsed and the pericardium incised widely, anterior to the phrenic nerve.

The left auricle is entered from the left auricular appendage and the surgeon's index finger is inserted through the appendage and into the auricle, the mitral valve being split at either commissure. In figure 2 the finger is seen passing through the left auricle and the mitral valve. The finger is then withdrawn, a special clamp is applied to the base of the appendage, and the latter is amputated after suture of its base. The pericardium and thorax are then closed in layers, the left lung being fully re-expanded before closure of the chest and a water-sealed drain left in place.

## ANAESTHESIA

I regard the following as the basic essentials in any anæsthetic technique for the operation of mitral valvotomy.

(1) *Adequate oxygenation of the patient at all times.*
(2) *Complete control of respiration.*
(3) *Reduction of cardiac irritability.*

FIG. 2

Diagrammatic representation of the surgeon's finger in the mitral valve
The wall of the left ventricle has been resected.

(4) The Anæsthetic Drugs of choice should be *non-irritable to the myocardium, non-toxic* to other tissues, preferably be *non-inflammable*, and to allow of a *quick recovery rate* with *minimal post-operative sequelae.*

(1) *Adequate oxygenation.* Adequate oxygenation, essential at all times during anæsthesia, is vitally so during intra-cardiac surgery. The heart in mitral stenosis is already working under a severe handicap and, if the oxygen content of the blood is allowed to fall, serious results will ensue, both as regards the myocardium and the cerebral tissues.

(2) *Complete control of respiration* is obtained by the use of d-tubocurarine chloride and voluntary respiration is further prohibited by the use of a Waters' to-and-fro absorber connected to a cuffed endotracheal tube. In the more recent cases use has been made of the Blease Pulmoflator, with great success. This apparatus administers any previously determined tidal volume, the intra-pulmonary pressure can be set and the rate and length of inspiration and expiration adjusted at will. The Pulmoflator is undoubtedly a great asset to the single-handed anæsthetist in intra-cardiac or thoracic surgery.

(3) *Irritability of the myocardium.* The myocardium resents handling and reacts to it with many varied arrhythmias. These may vary from the simple auricular extrasystole to frank auricular fibrillation. Partial or complete heart block may be seen, or varied ventricular extrasystoles heralding the onset of ventricular fibrillation, and sudden death may occur.

It has been known since 1942, when Lundy discussed the use of intravenous procaine, that this drug possessed a quinidine-like action on the myocardium, in that it pro-

longed the refractory period and at the same time reduced the conductivity of the conducting bundles. Burstein, in 1946, described its use in controlling cardiac irregularities during anæsthesia.

In the earlier cases of the series a 0.1 per cent solution of procaine hydrochloride in saline was used, but, as it was felt that the use of such quantities of intravenous saline might induce the onset of pulmonary oedema, the use of procaine in this form has been discontinued. Moreover, it is known that procaine hydrochloride is rapidly and completely destroyed in the blood plasma by the enzyme procaine-esterase.

Procaine amide, like procaine hydrochloride, depresses the irritability of the ventricular muscle. Unlike the latter, however, it is only partially hydrolysed by procaine-esterase so that its effect is much more prolonged. Its action occurs immediately after injection intravenously and the plasma level declines by about 10 to 15 per cent per hour.

Clinically the amide will abolish ventricular ectopic beats, paroxysmal ventricular tachycardia and ventricular extrasystoles, but has no effect on persistent auricular fibrillation or flutter. To correct ventricular arrhythmias during anæsthesia, procaine amide is given intravenously in a dosage of 100 mg. to 500 mg. (1 to 5 ml. of the 10 per cent solution).

The commonest side effect is hypotension and for this reason the drug should be given in divided doses. The usual practice is to give a test dose of 100 mg. and continue carefully with repeated increments of 100 mg., keeping a careful check on the blood pressure.

(4) *Anæsthetic drugs of choice.* Cyclopropane is relatively non-toxic to the tissues and allows an adequate blood oxygenation. The recovery period though rapid is not so rapid as with nitrous oxide, and I believe that there is an

increased incidence of post-operative vomiting and nausea with the former. At the same time cyclopropane can produce many undesirable arrhythmias and this is to be avoided at all costs in these cases. The explosive qualities of cyclopropane, moreover, forbids the use of diathermy inside the chest, and there seems to be little doubt that capillary oozing is increased with this agent.

Ether, similarly, is an explosive drug, and although relatively non-toxic to the myocardium and other tissues, the recovery period is slow and often accompanied by nausea, vomiting and possibly post-operative chest complications. Capillary oozing is similarly increased.

I consider that nitrous oxide in a 50 per cent mixture with oxygen, supplemented with intravenous pethidine hydrochloride is the anæsthetic drug of choice. Nitrous oxide is non-toxic to the myocardium in this percentage, is non-inflammable, allowing the use of diathermy inside the chest, recovery is rapid and post-operative sequelae are minimal. The absence of post-operative vomiting in this series has been most striking. Pethidine hydrochloride gives adequate analgesic supplementation allowing a 50 per cent $N_2O:O_2$ mixture to be used and has a prolonged analgesic effect post-operatively. At the same time pethidine has, according to Burn (1950), a quinidine-like action on the heart in that it prolongs the refractory period. The drug, therefore, has a useful place in the realms of intracardiac surgery.

*Technique employed*

The premedication employed is papaveretum and scopolamine, the maximum dose being papaveretum 1/3 grain (20 mg.) and scopolamine 1/150 grain (0.45 mg.) given some $1\frac{1}{4}$ to $1\frac{1}{2}$ hours pre-operatively by subcutaneous injection.

When the patient is brought to the anæsthetic room, a cannula is inserted, under local anæsthesia, into the right internal saphenous vein at the ankle. An immediate slow blood drip is set up.

Anæsthesia is induced by the injection of up to 250 mg. thiopentone into the drip, followed by 15–20 mg. d-tubocurarine chloride which is then followed by another 100–250 mg. thiopentone. These doses, however, are adjusted according to the age and condition of the patient.

The lungs are then rhythmically inflated with oxygen for a period of two minutes in order to allow maximum jaw relaxation. The patient is intubated with the largest cuffed endotracheal tube that can be passed without trauma to the cords. The cords are not sprayed routinely with analgesic solutions.

It is important to check the position of the tip of the endotracheal tube, and inspection and auscultation of the chest must be routine in order to avoid the possibility of the tube having entered a main-stem bronchus. Controlled respiration with a 50 per cent $N_2O : O_2$ mixture is now commenced, and the patient is taken into the theatre.

The patient is now set up on the table in the lateral position, left side uppermost (fig. 3). The left arm is suspended from an arm rest, the right arm being placed beneath the patient's head with the arm fully flexed at the elbow.

A test dose of 25–50 mg. of pethidine is given shortly after induction and supplementary doses of 25 mg. pethidine and/or 5 mg. d-tubocurarine are injected into the drip as required. Slight voluntary movements, such as twitching of the fingers or eyebrows, indicate the need for a further increment of pethidine. A rising pulse rate similarly indicates the need for further pethidine, but in this operation this is not so reliable a sign, as the pulse may swing

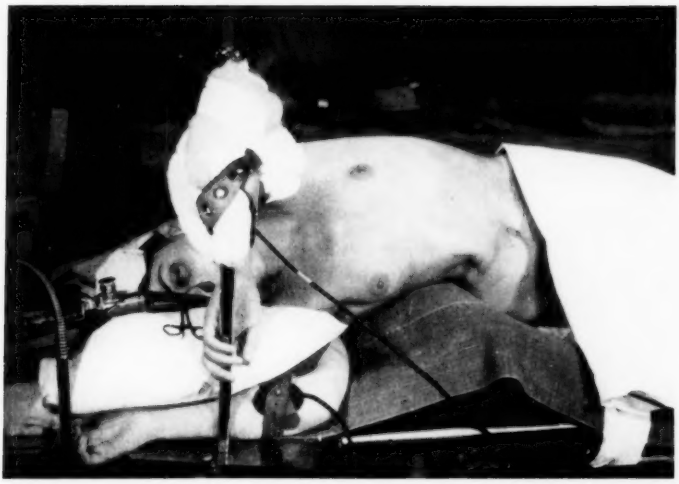

FIG. 3

Patient is shown in position on the operating table. The leads for the electrocardiograph can be clearly seen.

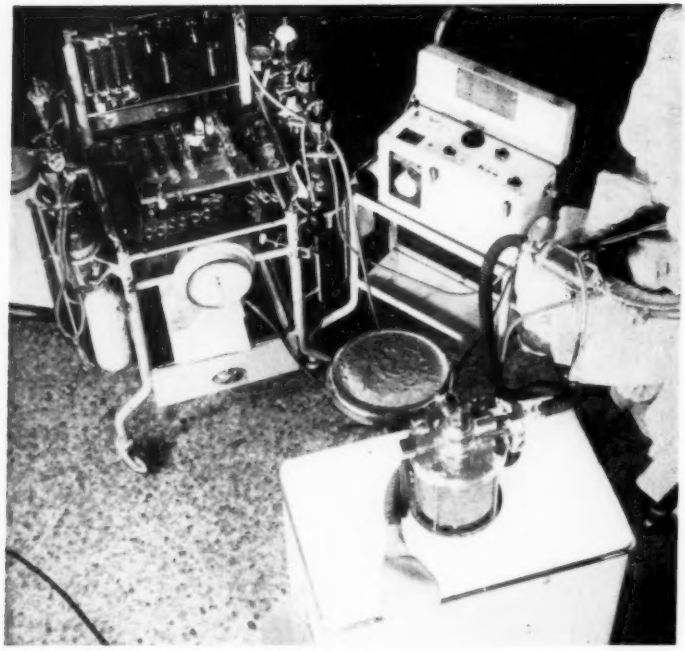

FIG. 4

View of head end of table to show Blease Pulmoflator and electrocardiograph in use during operation.

from time to time for other reasons. The Blease Pulmoflator is now connected up and the patient is automatically inflated 18–20 times per minute at a tidal volume previously determined (fig. 4). Usually this is about 500 ml.

Up to the exposure of the left auricle 100–300 mg. procaine amide is administered intravenously, depending on the state of irritability of the heart on direct handling. This is determined most easily by direct vision, but continuous electrocardiographic tracings, from a portable electrocardiograph are taken routinely. Lead II tracings are the most informative. An extra damping effect can be obtained at any stage by increasing the dosage of procaine amide and asking the surgeon to desist for a few minutes to allow the heart to settle. Handling of the left auricle should, if sufficient amide has been given, present little in the way of irregularities in rhythm or rate.

The blood pressure falls slightly following disruption of the valve (fig. 5) but should return to normal levels fairly quickly. The pulse rate shows no significant changes as a rule. Multiple ventricular extrasystoles are seen during the actual disruption of the valve, but there is usually an immediate return to normal sinus rhythm.

Closure of the pericardium may in some cases produce a marked bradycardia which is suggestive of vagal inhibition, but this can be quickly corrected by the administration of atropine intravenously (fig. 6).

As soon as the base of the appendage has been sutured a definite attempt should be made to inflate the lung and the surgeon must be requested to desist from the operation at this stage. It is important that all lung lobules are fully inflated, as it may be found impossible to do this at the end of the operation. In fact it is of great advantage to the patient to inflate the lung several times during the course

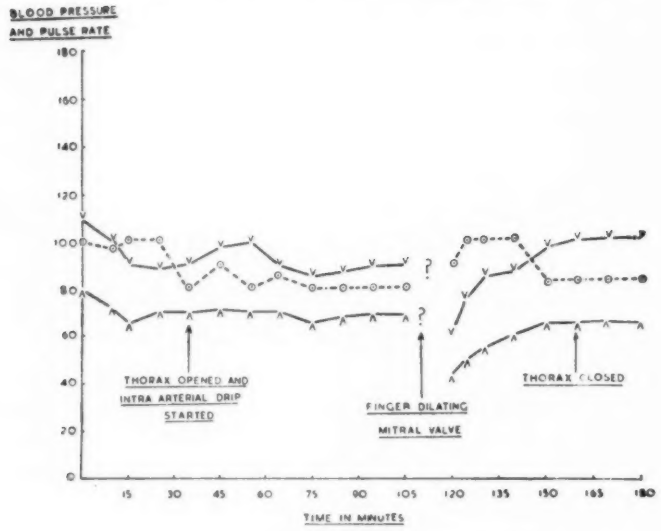


FIG. 5
Figure to show slight fall in blood pressure following disruption of the mitral valve

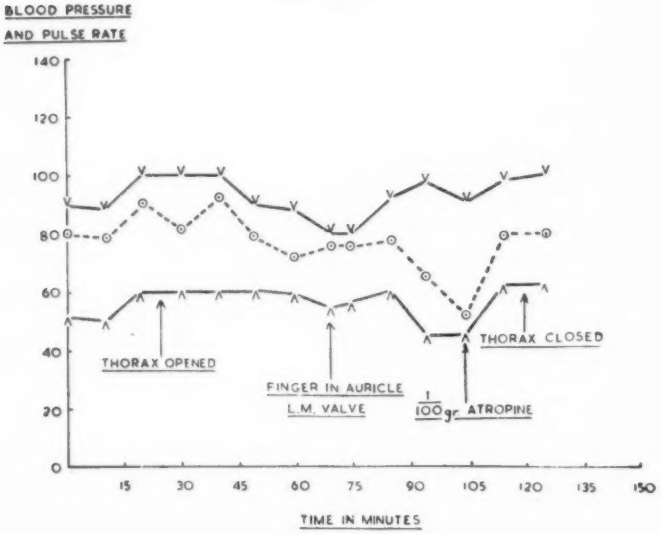


FIG. 6
Showing the effect of intravenous atropine in a case of bradycardia following closure of the pericardium

of the operation. On closure of the chest the lung must be fully inflated. An intercostal drain is led under a water-seal, any air which is left in the pleural cavity being displaced by inflation of the lung.

On removal of the absorber spontaneous respiration returns, and the operation is completed by a thorough toilet of trachea and bronchi. Much importance is attached to this procedure as the patient must not be returned to the ward with his trachea and bronchi full of secretions. Bronchoscopy should be performed if there is any doubt regarding fluid in the bronchial tree.

In the ward the patient is placed in an oxygen tent through which a flow of 6–8 litres of oxygen per minute is run. A careful watch is kept on pulse rate, colour, blood pressure and respiration. Little sedation is required at first, but pethidine usually gives adequate analgesia.

In the most recent cases, in an attempt to cut down post-operative chest pain, patients have been given an intercostal block, above and below the wound to the extent of two spaces with 1 to 2 ml. of Efocaine in each intercostal space. This drug will, in the average case, produce analgesia lasting from 8 to 14 days. So far in the limited number of cases so treated, the results have been most gratifying, as the patient is able to take deep breaths without chest pain right from the first post-operative day.

It is surprising how well these cases look post-operatively, and they can be seen within a few hours sitting propped up in bed inside their oxygen tents. The oxygen tent is usually dispensed with by the second day, unless there is some residual cyanosis.

## RESULTS

To date I have administered anæsthesia to some 33 of these cases. On the debit side two cases unfortunately died in the post-operative period.

*Complications during operation*

In the first case, a male aged 37 years, a large number of organized thrombi were discovered on opening the auricular appendage. In order to prevent their reaching the cerebral circulation the surgeon asked me to compress both common carotids. This was done with the result that the heart ceased to contract for 12 seconds (fig. 7) and on

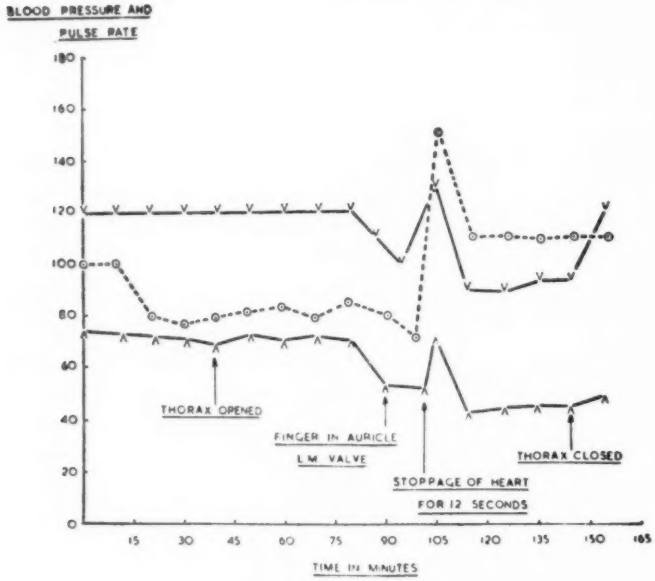


FIG. 7

Case in which the heart stopped for twelve seconds following compression of both carotid arteries.

resumption of contraction numerous bursts of ventricular extrasystoles were seen. Two ml. of 2 per cent procaine and 1/1000 adrenaline were injected into the left ventricle with a gradual return to normal rhythm. This was undoubtedly a case of vagal inhibition following stimula-

tion of the carotid body reflex. This could have been prevented by the administration of atropine before compression, but in the emergency no time was allowed for this.

The patient recovered subsequently, but commenced to fibrillate on the third post-operative day. Cyanosis and dyspnoea were present and both increased. Large pleural effusions formed, especially on the left side, one litre of fluid being aspirated. Death occurred on the tenth post-operative day due to progressive cardiac failure. Autopsy revealed a mitral valve which had only been split very slightly at one commissure.

During the second case, a female of 38 years, the surgeon unfortunately lost control of the auricular opening during the actual splitting of the valve. There was a sudden loss of some $1\frac{1}{2}$ pints of blood. The blood pressure fell to unrecordable depths, the heart being grossly irregular with multifocal ventricular extrasystoles. The patient, however, improved, but unfortunately died on the second post-operative day due to cardiac failure. There was massive bilateral pleural effusions and examination of the valve revealed a tiny split at one commissure only.

*Post-operative complications*

As regards post-operative complications, table I shows the main complications in the 32 cases.

One of the commonest has been that of auricular fibrillation and this has occurred most frequently from the third to the fifth day. Ten cases showed fibrillation in this period, but of these, five were fibrillating before, during and after operation. Routine quinidine administration from the first post-operative day seems to a large extent to control most of these potential fibrillators, but again some respond better to digitalis and digoxin.

The next commonest complication has been that of

TABLE I
*Post-operative Complications in 33 Cases*

| | | | |
|---|---|---|---|
| 1. *Cardiac Irregularities*: | | | |
| (A) Auricular fibrillation ... ... ... | | 10 | (5) |
| (B) Partial heart block ... ... ... | | 1 | |
| 2. *Chest Complications*: | | | |
| (A) Atelectasis: | | | |
| left lower lobe ... | | 2 | |
| other lobes ... | | 2 | |
| (B) Pleural effusions: | | | |
| large bilateral ... | | 2 | |
| small left basal ... | | 6 | |
| (C) Pericarditis with effusion ... ... | | 1 | |
| (D) Dyspnoea (undiagnosed) ... ... | | 1 | |
| 3. *Other complications*: | | | |
| (A) Vomiting ... ... ... ... ... | | 3 | |
| (B) Thrombosis (calf veins) ... ... | | 1 | |
| (C) Nerve palsy ... ... ... ... | | 1 | |
| (D) Mental changes ... ... ... ... | | 1 | |
| (E) Cyanosis ... ... ... ... ... | | 2 | |

collapse of the left lower lobe with or without small left basal effusions. Adequate re-expansion of the lung at frequent intervals during the operation seems to be the answer as regards the lower lobe collapses, and maintenance of a patent drainage tube should prevent the collection of basal effusions.

One case of pericarditis with effusion occurred, but this was undoubtedly due to the use of 4 per cent procaine inside the pericardial sac, a procedure now abandoned.

Vomiting in this series has been seen only on rare occasions. In three cases vomiting was severe, and was undoubtedly due to overdosage with digitalis, as on the withdrawal of this drug vomiting ceased.

A temporary paralysis of C5 and C6 roots on the left side occurred in one patient due to faulty placing of the left arm, but happily complete recovery took place after three months.

In another case severe mental changes of an emotional character took place after the operation. As there was no evidence of motor loss, the presence of a cerebral embolus can only be conjectured, but the surgeon reported the presence of several emboli in the left auricular appendage at operation, and it is possible that one may have entered the cerebral circulation. Further, compression of both carotid arteries in this case may have caused some permanent cerebral damage from anoxia of brain cells.

As regards post-operative sedation, I was surprised to find that the average amount of pethidine used post-operatively over the first ten days was in the region of 1,800 mg. Since performing intercostal blockade of the wound with Efocaine this figure has been reduced to 900 mg. This is undoubtedly a significant drop. Pethidine is not administered routinely but only when the patient really requires relief of pain. There is no doubt that a properly performed intercostal block with Efocaine will cut down post-operative chest pain, and at the same time reduce the amount of sedative required in this period.

## SUMMARY OF ANAESTHETIC TECHNIQUE

In conclusion I should like to summarize the anæsthetic technique I have employed in the operation of mitral valvotomy.

1. *Induction.* Thiopentone.
   *Maintenance.* 50 per cent $N_2O$: $O_2$,+ pethidine.
2. *Adequate oxygenation throughout operation.*
3. *The use of curare and controlled respiration.*
4. *Reduction of myocardial irritability with procaine amide.*
5. *Average total dosage of anæsthetic drugs used in* 32 *cases:*

| | |
|---|---|
| Thiopentone - - - - - | 400 mg. |
| d-Tubocurarine chloride - | 35 mg. |
| Pethidine - - - - - - | 118 mg. |
| Procaine amide - - - - - | 275 mg. |

Finally, I should like to thank Mr. W. Arthur Mackay and Mr. Kenneth Fraser for permission to publish their cases, also I am indebted to Dr. A. G. Miller and Dr. H. H. Pinkerton for much help and useful criticism in the preparation of this paper.

REFERENCES

Bailey, C. P. (1949). *Dis. Chest*, **15**, 377.
Baker, C., Brock, R.C., and Campbell, M. (1950). *Brit. med. J.*, **1**, 1283.
Brock, R. C. (1950). *Proc. R. Soc. Med.*, **44**, 995.
Brunton, L. (1902). *Lancet*, **1**, 352.
Burn, J. H. (1950). *Brit. med. J.*, **2**, 691.
Burstein, C. (1946). *Anesthesiology*, **7**, 113.
Lundy, J. S. (1942). *Clinical Anesthesia*, Philadelphia: Saunders.
Murray, G. (1950). *Arch. Surg., Chicago*, **61**, 903.
Pribram, B. O. (1926). *Arch. klin. Chir.*, **142**, 458.
Smithy, H. G., Boon, J. A., and Stallworthy, J. M. (1950). *Surg. Gynec. Obstet.*, **90**, 175.
Souttar, H. S. (1925). *Brit. med. J.*, **2**, 603.

*Brit. J. Anæsth.* (1953), **25**, 315

*REVIEW ARTICLE*

# PHYSICAL METHODS OF GAS ANALYSIS

By RONALD WOOLMER

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METHODS of gas analysis are becoming increasingly important to anæsthetists.

Gases may be analyzed by chemical and by physical methods. Chemical methods generally involve the conversion of the gas into a non-volatile compound. It may then be estimated by titration or by some other chemical reaction, or by measurement of the volume of the remaining gas.

Chemical methods can be very accurate, but they are slow and laborious. They are not suited to continuous sampling, and the information they convey comes too late to influence the conduct of a specific anæsthetic.

If the conduct of anæsthesia is to be influenced by the result of gas analysis, the method must be rapid. Indeed, it may be required to show the changes occurring during a single breath. Though few physical methods are quick enough for this, they are nevertheless vastly quicker than chemical methods; many of them are adapted to continuous sampling, and many are applicable to gases which are chemically inert.

## PHYSICAL METHODS

Some physical properties of gases are absolutely specific. Among these are molecular weight, wavelength (or frequency) at which electro-magnetic radiation is emitted or absorbed, and relationship of ionic mass to ionic change. Others are less specific, but can be used in suitable cases. They include heat conductivity, velocity of transmission of sound, magnetic susceptibility, refractive index and viscosity.

*Infra-red methods.* A method of measurement which depends on the specific absorption or emission of radiant energy is infra-red gas analysis. Most gases will absorb energy from a beam of infra-red light falling on them, though oxygen, nitrogen and hydrogen are exceptions. These three gases are affected by radiation in the ultraviolet region of the spectrum. The radiation emitted by a heated platinum or nichrome wire extends from visible red light to the far infra-red region (from 0.6 $\mu$ to 3 $\mu$, or $5 \times 10^{14}$ cycles per second to $1 \times 10^{14}$ c/s.),* and so covers a fairly wide range of frequency or wavelength. The fraction of this energy which can be absorbed by an individual gas, however, is sharply limited to certain definite frequencies, and these are characteristic of the gas. A particular gas in a mixture of gases may thus be detected and measured by the amount of energy, of the frequency characteristic to that gas, lost by the beam in its passage through the mixture.

The amount of radiation absorbed is measured by its heating effect on the absorbing gas. The detector of such radiation is usually a closed absorption cell containing gas, to which is attached a means of measuring change of temperature directly or indirectly. Direct measurement may be by a thermocouple and amplifier; indirect measurement by measuring the changes in pressure caused by changes in temperature of the gas in a closed chamber. As such pressure changes are small, they have to be measured by converting the very small movement of a diaphragm into a change in some electrical quantity such as capacitance or conductance. This is then amplified and recorded by a capacitance manometer or an electronic transducer.

For analysis by infra-red radiation, a sampling cell is placed between the source and the detector, and the gas under test is made to pass through it (fig. 1).

* These units are further explained in the Appendix.

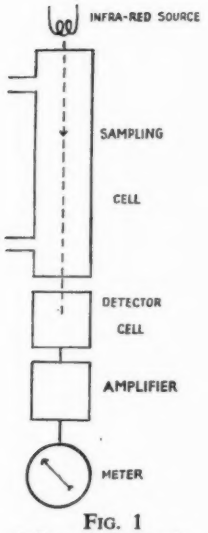


FIG. 1
Infra-red absorption meter.

If the gas in the sampling cell can absorb infra-red radiation, the energy reaching the detector will be proportionately reduced. It is of course necessary for the atmosphere in the detector cell to include every gas which is to be presented to the sampling cell, as the detector is blind to frequencies which its contents cannot absorb. This is a very sensitive means of detecting gases which have absorption spectra anywhere in the wide range of frequencies emitted by the source (Fastie and Pfund, 1947). In this form it is unspecific, however, since it cannot distinguish between one absorbing gas and another.

There are two ways of making the detection specific. The first is the positive filtering method.

An absorption cell is placed beyond the sampling cell, and the detector is arranged to measure changes of temperature in its contents. If this absorption cell is filled with the pure gas to be detected—$CO_2$ for instance—it will absorb that part of the energy of the beam which is in its own particular frequency, and transmit all the rest. This cell has thus put " blinkers " on the detector, so that it can see only $CO_2$. If now the gas in the sampling cell contains $CO_2$ it will there absorb from the beam some of the energy to which the detector uniquely responds. The detector's response will therefore be lessened, and the reduction will be proportional to the concentration of $CO_2$ in the sampling cell. After it has passed through the first absorption cell, the beam—deprived only of the frequencies characteristic

of $CO_2$—can be made to pass through a series of other absorption cells responsive to other gases. In practice this instrument is usually arranged in duplicate. The beam is split into two halves, either by mirrors, as described by Fowler (1949), or by a prism. One half is directed into the sampling cell, and the other half into a similar cell containing a reference gas, such as air (fig. 2). The beams then pass through two absorption cells, containing the same gas as it is desired to measure. A detector cell connected to these two cells records the difference in the temperature, or pressure, of the contained gas. This difference will be

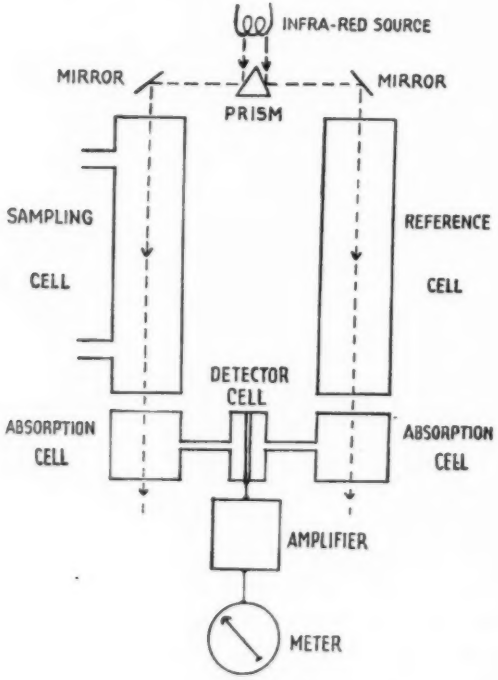


FIG. 2
Positive filtering method.

proportional to the difference, between the sampling cell and the closed reference cell, in abundance of the gas being measured. This differential method ensures that changes in rate of emission of the source and in the temperature of the gases in the sampling cell will affect both cells equally and will thus be automatically compensated.

Analyzers of this type are made by several firms in Britain. They have a number of commercial and scientific uses, and can analyze many gases, such as $CO_2$, ether, $N_2O$, CO, $C_2H_4$.

The other way of making the detector selective is the negative filtering method.

A cell filled with whatever gas is to be measured is placed between the sampling cell and the absorption-detector unit. This cell absorbs all the energy in the specific frequency of the gas, and the detector, so shielded, is blind to this gas but responsive to all others provided they are represented in the absorption cell.

The greater the proportion, in the sampling cell, of the gas to be measured, the less will be the proportion of other gases, and so the less will be the energy transmitted to the detector. If the sampling cell should happen to contain nothing but the gas being measured, no radiant energy would get through the filter to the detector cell. In practice this instrument, too, employs duplicate cells (fig. 3), and both are equally affected by changes in emission and in ambient temperature.

The negative filtering method is inferior to the other because it depends on the small difference between two large signals and because the beam cannot be further analysed (Williams, 1948).

A more direct method of measuring the absorption is to allow the beam to fall on to a photo-electric cell. The electrical resistance of such a cell varies with the intensity of

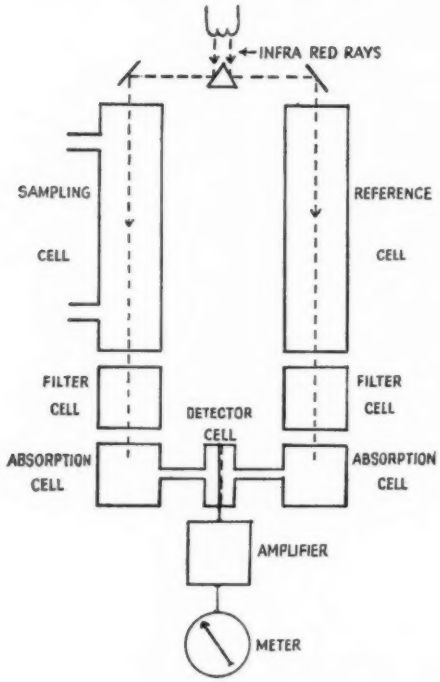


FIG. 3
Negative filtering method.

the radiation falling on it; but cells which are responsive to radiation in the far infra-red range are still in the experimental stage (Milner and Watts, 1952). The coating of these cells is lead sulphide, selenide or telluride, which when sufficiently cooled will respond to radiations in the far infra-red region down to 6 $\mu$ * (Chasmar et al., 1951). This is more than sufficient for the measurement of $CO_2$, which is the gas most likely to be measured by this means in respiratory studies. The normal pyrex (borosilicate) glass

* See Appendix.

envelope of photocells, however, will transmit radiations only down to 3μ (see fig. 4) so that energy at 4.3 μ, of which $CO_2$ is most absorptive, will not reach the cell. Synthetic sapphire ($Al_2O_3$) and "Periclase" (MgO) will pass the desired frequencies, and can be sealed to glass by appropriate techniques. The response of these cells is about 100 times quicker than that of the most sensitive thermocouple, and they will form the infra-red radiation detectors of the future. The need to keep lead photo-conductive cells cold for adequate sensitivity (some have to be cooled to – 80° C.) would be an unwelcome complication; but it has been shown by Gibson (1952) that certain preparations of lead selenide have their maximum sensitivity in the required range at room temperature.

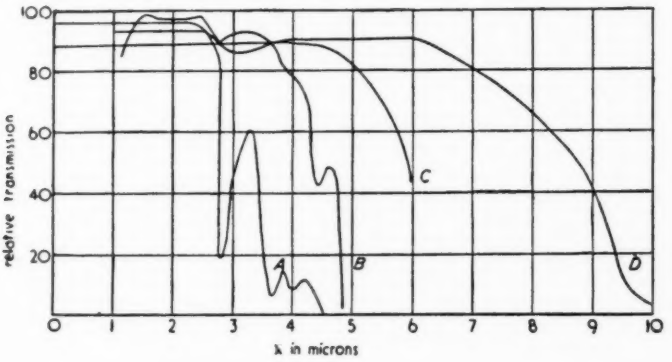


FIG. 4

Transmission plotted against wave-length for (a) pyrex glass, (b) sapphire and (c) "Periclase".
(From Chasmar, Cranston, Isaac and Young. 1951. Reproduced by courtesy of The Institute of Physics.)

*Ultra-violet radiation.* Nitrogen and oxygen have absorption spectra in the far ultraviolet and ultraviolet regions of the spectrum (around 990 Å and 1450 Å respectively).*

* See Appendix.

Oxygen has the strongest absorption, in its spectral region, of any gas known (Ladenburg and Voorhuis, 1935), but analysis by ultraviolet radiation has not yet been technically developed.

*Ionic radiation.* If they are provided with enough energy, such as heat or electrical energy, gases will emit radiation of their specific frequency instead of absorbing it. For some gases the frequency of this radiation falls within the visible spectrum, and a glow discharge results. The familiar neon discharge tube is an example of this. The intensity of the specific radiation will vary with the concentration of the gas responsible for it. This principle is used in a nitrogen meter devised by Lilly (1950) for the study of gas mixing in the lungs (fig. 5). The gas whose nitrogen content is to be measured is drawn at 0.5 to 1.0 ml./sec. through a quartz tube. Pressure in the tube is kept down to about 2 mm.Hg by a vacuum pump. Electrodes in the tube ionize the gas, which starts to glow. Nitrogen in the discharge tube glows bright orange-pink, and oxygen a faint green. Passing the emitted rays through colour filters excludes the light from all interfering gases, but lets through most of that from nitrogen, and these rays are focused on to a photocell. The current from the photocell is amplified and passed to a galvanometer whose mirror deflects a light beam on to a moving photographic film. The apparatus is cumbersome and expensive, but its response time is as short as one-fiftieth of a second and it is accurate.

*Mass spectrography.* Undoubtedly the most powerful method of gas analysis is the mass spectrography invented by F. Aston in 1919. This method depends on the fact that ions of different elements or compounds, travelling at high speed, are deflected to different degrees by a magnetic field. The gas to be analysed must first be ionized. That is to say

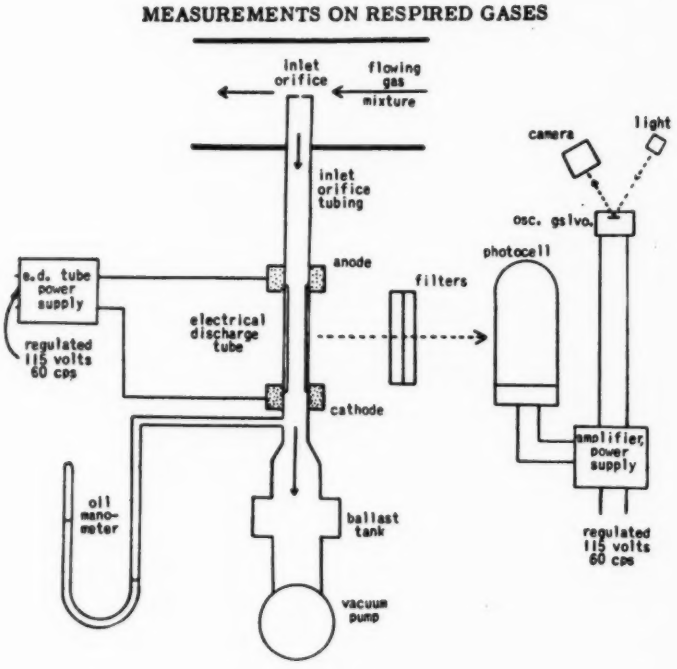


FIG. 5

Lilly's Nitrogen Meter.
(From Lilly, 1950. Reproduced by courtesy of The Year Book Publishers.)

electrons must be knocked out of the atoms so that they have a positive charge. This process requires energy, which has to be supplied at the ion source. The source of energy is usually a heated wire. The gas is fed into the ion source in very small amounts, a flow of the order of $10^{-4}$ to $10^{-5}$ ml./sec. being required. After admission to the spectrograph the gas is brought to a low pressure to reduce collisions between ions. Pressures of the order of $10^{-5}$ mm.Hg are required, so that a powerful vacuum pump is an essential part of the apparatus. The gas inlet and ion

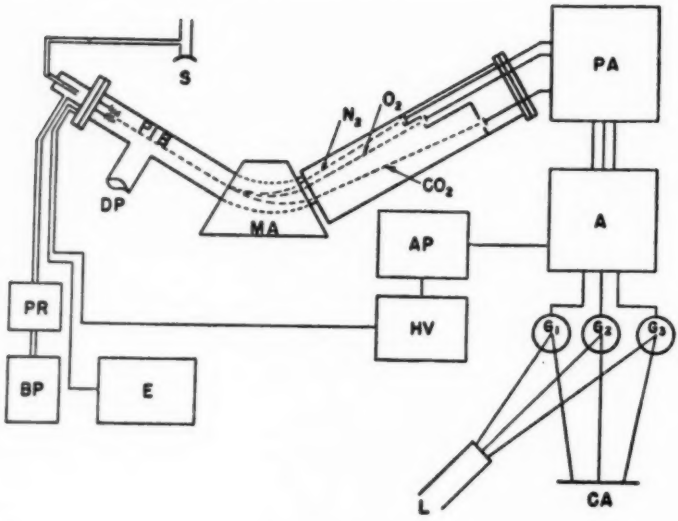


FIG. 6

Three detector mass spectrometer. S, subject; PR, pressure regulator; BP, bleeder pump; E, emission regulator; DP, to diffusion pump; PIB, positive-ion beam; MA, magnet; PA, pre-amplifier; A, Amplifier; AP, amplifier power supply; HV, high-voltage supply; L, light; CA, recording camera.

(From Hunter, Stacey and Hitchcock, 1949. Reproduced by Courtesy of American Institute of Physics.)

source is at one end of a tube, which also contains the anode for the accelerating voltage. The positive ions are accelerated away from the anode, down the tube towards the cathode. The tube is curved, and the ions follow the curve because they are pulled into a circle by a magnetic field. They do not all follow the same curve, however, because the heavier ions are less deflected than the lighter ones. Ions arriving at the cathode are thus spaced out in a line according to their masses. Slits placed at appropriate points on the cathode will allow ions of predetermined masses to pass through. The relative intensity of the different

ion masses—and hence the composition of the gas admitted to the ionization chamber—can be measured either by allowing the separated ion beams to fall on to a photographic plate or by amplifying the positive charges they contribute to the cathode and feeding the resultant current to a galvanometer or cathode ray oscillograph.

A practical application of the mass spectrograph to the analysis of respiratory gases (fig. 6) has been developed by Hunter et al. (1949). Slits are placed in the cathode at the points of impact of ions of nitrogen, carbon dioxide and oxygen (mass numbers 28, 44 and 32). A detector behind each slit records the intensity of the ion beam of its respective gas, and the current from each detector is amplified and led to a galvanometer. The galvanometers record their respective values simultaneously on moving photographic paper (fig. 7). The response time is a fraction of a second, and with suitable precautions the method is highly accurate. Most laboratory mass spectrographs are complicated and cumbersome pieces of apparatus, which cannot be taken to the patient. Siri (1947) however has invented a portable model which displays the ionic mass

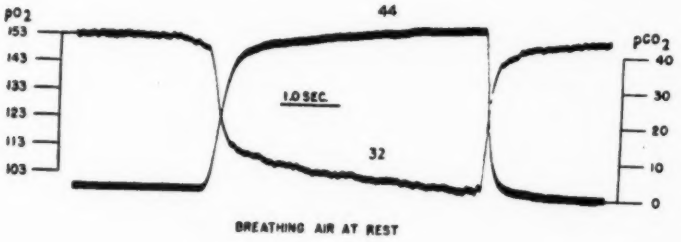


FIG. 7

Record of respiration by mass spectrograph. The record begins during an inspiration, shows one expiration, and ends during an inspiration. The trace marked 44 indicates the partial pressure of $CO_2$; that marked 32 the partial pressure of $O_2$.
(From Stacey, 1950. Reproduced by courtesy of The Year Book Publishers.)

numbers as spikes on a cathode ray tube. The abundance of the various gases can be immediately deduced from the heights of their respective spikes.

Miller (1950) and his co-workers have more recently developed another portable model, whose practical application has been described by Buckley et al. (1952).

The mass spectrograph is superior to all other methods as an analytical tool, and it is being increasingly used in science and industry. It is still a complex and expensive instrument, however, and its use demands a knowledge of physics which few anæsthetists can acquire. It will undoubtedly play an important part in the future.

*Paramagnetism.* Oxygen has nearly the same density, viscosity and thermal conductivity as air, so that its analysis by methods depending on these properties demands great accuracy and careful control. It is, however, unique in being strongly paramagnetic, which means that its molecules are attracted by a magnetic field. The only other gases to exhibit this property—and weakly at that—are nitric oxide, nitrogen peroxide and chlorine dioxide. An oxygen meter using the principle of paramagnetism, and arranged for continuous sampling, was devised by Pauling during the war (Pauling, 1946). It is an application of the principle demonstrated by Faraday 100 years ago. The Pauling meter has been manufactured for some years in the U.S.A., and is now being made in this country. It consists essentially of a small evacuated glass dumb-bell, weighing about 2 mg., which is suspended by a quartz fibre in an unhomogeneous magnetic field. If the atmosphere surrounding the dumb-bell contains oxygen, the dumb-bell, which contains none, will be repelled towards a region of lower magnetic flux density. This repulsion causes it to twist on its suspension, and the turning moment is proportional to the partial pressure of oxygen passing through the field. A small mirror attached

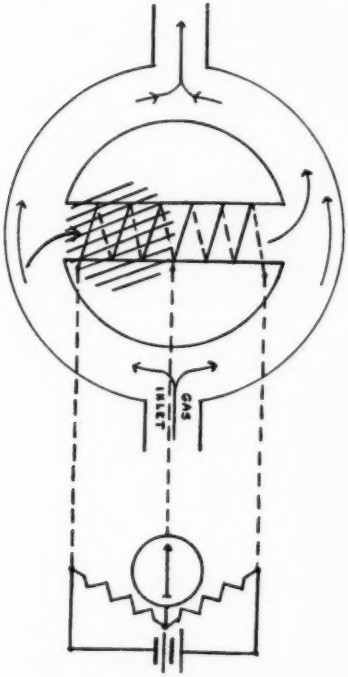


FIG. 8
Cambridge Oxygen analyser. For description see text.

to the suspension moves a beam of light over a scale which can be calibrated in partial pressure or in percentage of oxygen.

The gas is drawn through the instrument by the convection current set up by a heater coil. This heater, which is thermostatically controlled, also maintains the gas at constant temperature. This is important because the magnetic susceptibility varies inversely with absolute temperature. This dependence on temperature is put to ingenious use in another instrument, made in this country. In this the gas

path consists of an annular space bridged by a cross tube (fig. 8). The gas to be tested flows symmetrically through the annular space, so that the pressure at the two ends of the cross tube is the same. This cross tube is heated by a coil of platinum wire, and one end of it is in a magnetic field. Oxygen is attracted into this end of the tube, where the magnetic flux is densest. The heat imparted to it by the coil, however, makes it less paramagnetic, so that it seeks a region of lower flux density further along the tube to the right. Meanwhile more oxygen, which has not been heated and which is therefore more strongly paramagnetic, flows in to take its place. There is thus a flow from left to right along the tube, and this flow is proportional to the oxygen content and to the heating effect of the wire, which is kept constant. The heating wire plays a double part, for it is also used to measure the rate of flow. The resistance of a platinum wire varies with its temperature, and the temperature of the wire coil in the cross tube is affected by the flow of gas through it. The gas flowing into the cross tube has not been warmed whilst that flowing out of it has. The left half of the wire spiral is thus more cooled by the gas than the right half, and its electrical resistance is therefore lower. The lowering of the resistance is proportional to the gas flow, and this in turn is proportional to the oxygen content. The wire is tapped at the centre, and the two halves form two arms of a Wheatstone bridge. The electrical unbalance of the bridge is measured by a galvanometer which can be calibrated directly in oxygen percentage. In both these instruments the flow of gas into the analyser may be very small, and its rate does not affect the characteristics, though in the Pauling meter a flow which is too fast will unbalance the dumb-bell.

Another British instrument uses the dumb-bell and light beam; but in this the beam is made to fall on to a photocell,

and the current from this is amplified and applied to an indicator or recorder.

Another application of the principle of paramagnetism, devised by Rein (1940), depends on the change in viscosity of oxygen as it passes into a magnetic field. In Rein's meter the gas stream to be analyzed is divided into two equal halves. Each half flows through a set of capillary tubes. One set is placed within the field of a permanent magnet, and the viscosity of the gas in this set differs from that in the other set. The difference is proportional to the oxygen percentage, and as it causes a change of pressure between the two halves it can be measured by a manometer.

*Audio-frequency.* The velocity of sound in a gas depends on its specific heat and on its density, and it differs fairly widely from one gas or vapour to another. In many cases it is therefore possible to determine the relative proportions of two or more gases in a mixture by measuring the velocity of sound in it. There are various ways of determining this velocity. One method is to apply sonic vibrations of known frequency (as, for instance, by a tuning fork) to a closed column of the gas of variable length (fig. 9). Resonance will occur when the length of the column is half the wavelength of the emitted note. The velocity is equal to the frequency (which is known), divided by the wavelength, and can thus be readily determined. Dublin et al. (1940) have used this method to analyze mixtures of oxygen, helium and nitrogen.

Faulconer (1949) has made use of the same principle in determining the tension of ether vapour in ether-air mixtures. He used a small brass tube, with a microphone at one end, and a telephone receiver at the other.

Sound pulses pass across the gasfilled tube, are picked up by the receiver, amplified and passed to the microphone again. The circuit thus functions as an oscillator, and the frequency of the cycle varies with the velocity of sound in

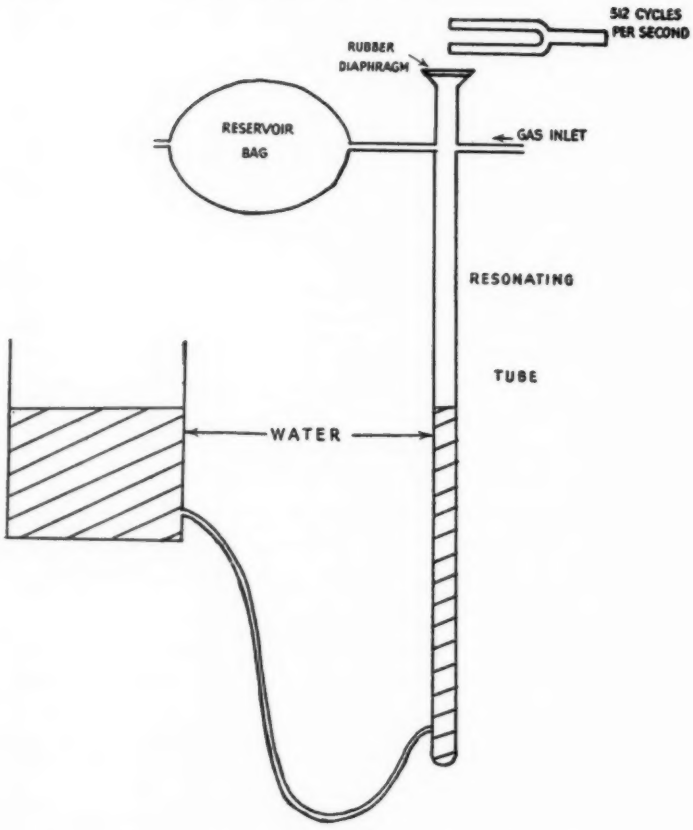


FIG. 9
Method of determining the velocity of sound in a gas.
(After Dublin, Boothby and Williams, 1940.)

the tube. This frequency is determined by matching on an oscilloscope with an oscillator of known frequency (fig. 10). Much care and patience is needed in the calibration of this instrument, but it is capable of good results.

*Thermal-conductivity.* Another important method of gas analysis is the thermal conductivity method. Gases

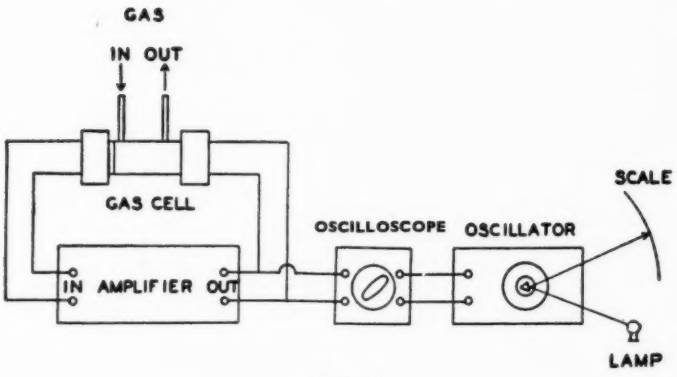


FIG. 10

Oscillator type of acoustic gas analyser.
(From Faulconer, 1949. Reproduced by courtesy of The American Society of Anesthesiologists.)

differ in their conductivity though the difference is in some cases small—and suitable mixtures of two gases can be accurately analyzed by this means. The mixture to be tested is passed into a tube containing a heated platinum wire. Platinum is chosen because its resistance varies considerably with its temperature. What has to be found is the heat supplied to the wire and the heat lost by the wire in unit time. The ratio of these quantities will vary with the thermal conductivity of the gas.

The same electric current is used for two purposes: to heat the wire and to measure the heat supplied and the heat lost. The heat supplied is the product of the current put into the wire and the potential difference along it. The electrical resistance of the wire varies with its temperature. This in turn varies with the rate of heat loss, which is dependent on thermal conductivity. Hence from the simple electrical measurement of current and potential difference in the wire the thermal conductivity of the gas surrounding it can be deduced (Daynes, 1933). It is, however, unneces-

sary to measure the thermal conductivity in absolute units. It is sufficient to compare the conductivity with that of a reference gas. This can be reduced to the comparison of two electrical resistances in a Wheatstone bridge, with empirical calibration. The gas to be tested is admitted to one cell, the known reference gas to a precisely similar one (fig. 11). The two cells are placed close together, and are made of a material of high thermal conductivity, such as

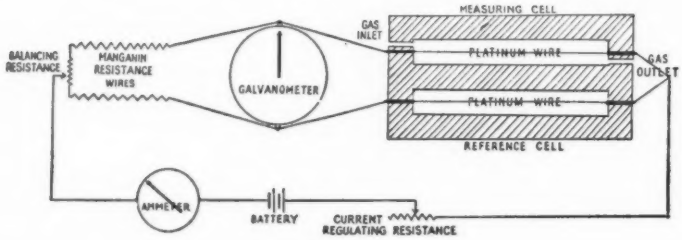


FIG. 11
Thermal conductivity meter.

copper, so that any changes in ambient temperature will affect them equally. The two platinum resistances are contained in these two cells. The other two resistances, forming the third and fourth arms of the Wheatstone bridge, are usually made of manganin, whose resistance varies but little with change of temperature. The galvanometer may be calibrated directly in percentage of the gas to be tested, or the null method may be employed. In this, a slide wire potentiometer, connected in series with one of the resistances, is used to rebalance the bridge. The potentiometer reading, taken when the galvanometer has been brought back to zero, gives the percentage of the constituent being analyzed. The differential method of comparing the unknown with a reference gas lessens the importance of accurate control of heating current and of temperature

conditions, which would otherwise limit the value of the method.

The hot wire bridge, in its various forms, is much used in industry, to measure the amount of $CO_2$ in flue gases, the amount of methane in mines, the amount of argon in oxygen, the leakage or diffusion of hydrogen from balloons, the amount of water vapour in the air, and so on, and it has proved accurate and practical, but its potential errors must be understood and allowed for. For instance, large errors can be introduced by the presence of $CO_2$ when gases other than this are being measured, since its thermal conductivity is much higher than that of other respiratory gases (Lilly, 1950).

The time lag for a conductivity bridge instrument varies from thirteen to sixty seconds, and is inversely proportional to the diffusion constant of the gas mixture. The rate at which gas should pass through the cell is usually less than 20 ml./min.

The ideal mixture for analysis by the conductivity method is one consisting of two components of very different conductivities (Daynes, 1933). But even gases of very similar conductivity, such as nitrogen and oxygen, can be accurately measured, if enough attention is paid to detail and to the elimination of such errors as zero drift and conduction losses. In certain cases, the concentration of a particular gas in a mixture of several gases may be conveniently measured. The simplest method is to pass the mixture in sequence through one cell of a differential conductivity meter, then through an absorbent which will completely remove the constituent to be measured, then through the second cell of the meter. The difference in conductivity is then due to the constituent which has been removed, and its abundance can hence be calculated.

Various types of conductivity meter have been devised

for the analysis of respired gases. Knipping (1924) used a German apparatus for the measurement of carbon dioxide in alveolar air. Ledig and Lyman (1927) in the U.S.A. used a meter to measure carbon dioxide and oxygen in the same sample. Berg (1947) has used a differential conductivity meter to measure respiratory gas exchange under various physiological conditions, with satisfactory results. Pask (1952) has applied the method to measure the concentration of trichlorethylene delivered by various inhalers.

*Combination of acoustic and infra-red.* An ingenious combination of an infra-red method and an acoustic method has been applied by a Russian worker (Vengerov, 1946) to the measurement of ether vapour in air. The gas to be analyzed is passed into a closed tube which has a beam of infra-red rays entering at one end, and a microphone let into the other. The beam is interrupted by a revolving disc at a sonic frequency, namely 200 per second. If the gas absorbs energy from the infra-red beam, it will undergo an increase in pressure 200 times a second. The gas will thus pulsate at sonic frequency, i.e. sound will be produced. The pitch of the sound will depend on the frequency of interruption of the beam, and its amplitude on the ability of the gas to absorb energy. By this method it is claimed that with suitable amplification the presence of 0.1 mg. of ether vapour can be determined in a litre of air. Air itself will of course be "silent", since neither oxygen nor nitrogen will absorb infra-red rays. The apparatus is, however, quite unspecific in that it will respond to any gas that can absorb energy in the applied frequency range. It could be made specific by the use of filters as already described for infra-red analysis.

*Refractive index.* The refractive index may be used to estimate gases and vapours, and this method was used to calibrate the Oxford ether vaporizer (Epstein, 1952), and

by Bell and Krantz (1940) to measure the concentration of nitrous oxide. The analyzing beam is split into two halves which traverse the length of two parallel cells. One cell contains a reference gas, such as air; the other contains the sample. After traversing their respective cells, the beams are re-combined into the same optical path. A difference in refractive index of the two gases results in a slight difference in the time of transit through the two light paths, so that the light waves arrive out of phase and produce interference fringes. The fringes can be made to coincide by the rotation of a prism in one of the light paths, and after empirical calibration the rotation required gives the concentration, in the sample, of the gas to be measured. For the best results a refractometer, or interferometer, as it is also called, needs a long light path, and monochromatic (sodium) light. It is a laboratory instrument. It has recently been used by Hall et al. (1953) for measuring the concentration of trichlorethylene delivered by various inhalers.

### CHEMICO-PHYSICAL METHODS

Chemical methods of analysis are usually discontinuous, and the gas sample cannot be returned unchanged to the system. This disadvantage can sometimes be got over by a combination of chemical and physical methods. Such a combination is seen in the absorption bridge analyser. In this four capillary tubes, $C_1$–$C_4$, are joined as shown in figure 12. The gas drawn into the inlet divides at A into equal parts. One part flows through $C_1$ and $C_2$ to the outlet. The other part flows through $C_3$, the absorption tube, and $C_4$ to the outlet. Reduction in volume due to absorption of the constituent to be measured in the U-tube causes a difference in pressure between points D and E. This pressure change can be indicated by a U-tube or other type of manometer, which may be calibrated in percentage of

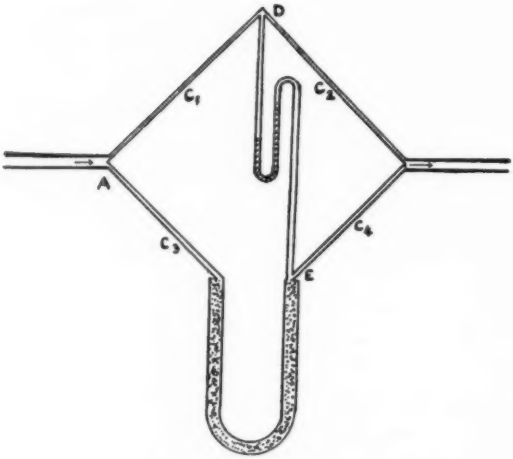


FIG. 12
Chemical absorption bridge.

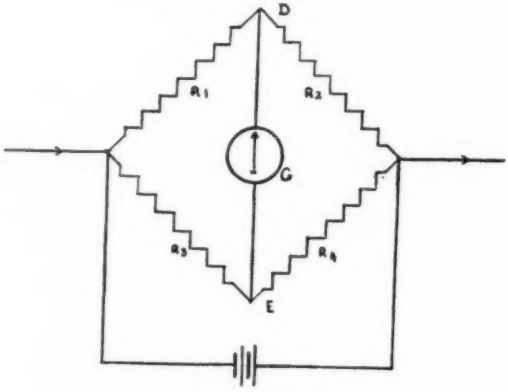


FIG. 13
Electrical resistance bridge.

the gas being measured. This method has its counterpart in the measurement of various physical quantities, such as temperature and thermal conductivity, by the Wheatstone bridge (fig. 13), which has already been referred to. The

analogy between the chemical absorption bridge and the electrical resistance bridge will be apparent. The bridge gas analyser has several industrial and research applications such as the analysis of exhaust gases, and it has been applied to the estimation of $CO_2$ in respiration and during anæsthesia by Ringrose, Rowling and Harbord (1950). In their R.R.H. $CO_2$ indicator (fig. 14) the gas to be tested is passed through a chamber containing two porous cylinders C and

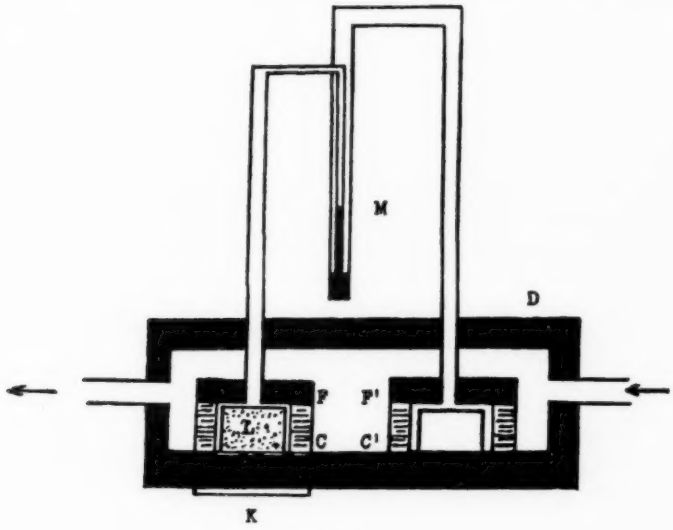


FIG. 14
The Ringrose-Rowling-Harbord $CO_2$ Analyser (diagrammatic).
(From Ringrose, Rowling and Harbord, 1950.)

$C_1$. Cylinder C contains soda lime and $C_1$ an inert substance of equal volume. Carbon dioxide diffuses into C and is absorbed. This sets up a pressure difference in the limbs of the U-tube manometer. The scale of the manometer M is calibrated in percentage of $CO_2$.

Another chemico-physical method for the measurement

of $CO_2$ has been successfully applied by Brinkman (1952). In this the sample is bubbled through an indicator solution. Changes in $CO_2$ content induce colour changes in the indicator, because they alter the hydrogen ion concentration, and these colour changes are measured by a photo-cell. After calibration, the galvanometer attached to the photo-cell can indicate the percentage of $CO_2$ directly. Brinkman's instrument is sensitive and compact, but it is expensive.

Soap film analysis was introduced by Gooderham (1948) and is shown in figure 15. The gas flows through two similar

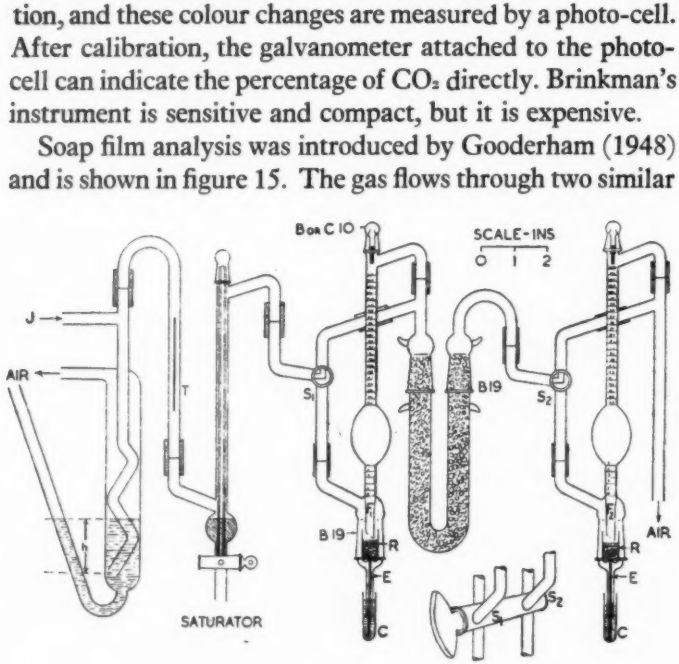


FIG. 15

Gooderham's Soap Film Analyser (diagrammatic). (From Gooderham, 1948. Rreproduced by courtesy of Griffin and Tatlock Ltd.)

measuring tubes F, between which is placed an absorber, such as soda lime if $CO_2$ is to be measured. A cup R, below each measuring tube, contains soap solution. If this cup is momentarily raised, a soap film is formed across the lower end of the tube, and is carried upward by the gas stream. The gas flows through a capillary tube T which is backed

by a blow-off to limit fluctuations in driving pressure, and enters the measuring device by the tap S. The position of this tap determines whether it will flow through F, or by-pass it. By manipulation of the tap, a soap film which has been formed can be left stationary near the bottom of $F_1$. After traversing the absorber the gas arrives at $S_2$. This tap, which is on the same spindle as $S_1$ and turns with it, similarly determines whether the gas will flow through $F_2$ or by-pass it. A soap film is formed also in $F_2$ and held stationary near its lower end. The position of the two stationary soap films is read and the taps S are then turned so that gas flows through tubes F. When the film has passed through 100 divisions in $F_1$, S is quickly turned again so that the gas by-passes both measuring tubes and the soap films are stopped. If the film in $F_1$ has passed through 100 divisions, and that in $F_2$ through ninety-five, the volume of the sample has been reduced, in the U-tube, by 5 per cent, and this is therefore the proportion of $CO_2$ originally present.

This type of meter has several advantages. It is a direct displacement meter, which does not require calibration against a secondary standard. There are no moving parts, and it is very compact. (The diagram, figure 15, gives an expanded view.) It introduces no back pressure and requires no correction for temperature changes.

Several other types of gas analyser exist. They differ in detail, but not in principle, from those described; and they have the advantage of permitting rapid and continuous analysis of respired gases to be made.

## APPENDIX

The electromagnetic spectrum covers an enormous range, and its radiations manifest themselves as gamma rays, X-rays, ultraviolet rays, visible rays, heat rays, or radio (Hertzian) waves according to their frequency or wavelength. The ratio between the frequency

and the wavelength of any electromagnetic radiation is fixed. It is expressed by $v = f.\lambda$, where $v$ is the velocity of light, or $3 \times 10^{10}$ cm. per sec., $f$ is the frequency per second, and $\lambda$ is the wavelength in cm. Hence for a frequency of $10^6$ c/s, or one megacycle, the corresponding wavelength is $\frac{3\times10^{10}}{10^6} = 3\times10^4$ cm., or 300 metres. This would put it in the medium broadcasting waveband.

Any part of the electromagnetic spectrum can be referred to quite unambiguously either by its frequency or by its wavelength in cm. But because the resulting number is not always of convenient size, and because many branches of science are each concerned with only a small part of the range, other units have gained currency. Thus for wavelength we have the Ångstrom unit (Å U) of $10^{-8}$ cm., the millimicron ($\mu\,\mu$) of $10^{-7}$ cm., the micron ($\mu$) of $10^{-4}$ cm. and the centimetre, the metre and the kilometre; and for frequency we have the kilocycle (kc/s) of a thousand ($10^3$) cycles per second, the megacycle (Mc/s) of a million ($10^6$) cycles per second, and the mega-megacycle (MMc/s) of $10^{12}$ cycles per second.

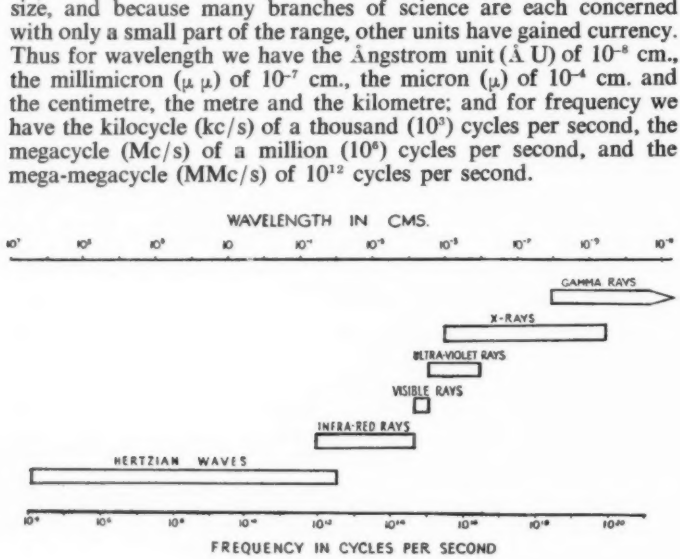


FIG. 16

The electromagnetic spectrum.

In representing the electromagnetic spectrum graphically on a linear scale, it is of course impossible to indicate more than a very small portion, and accordingly a logarithmic scale must be adopted to convey a comprehensive idea of it (See Fig. 16).

REFERENCES

Bell, F. J., and Krantz, J. C. (1940) et seq. *J. Amer. pharm. Ass.*, **29**, 126.

Berg, W. E. (1947). *Amer. J. Physiol.*, **149**, 597.

Brinkman, R. (1952). *Personal communication.*

Buckley, J. J., Van Bergen, F. H., Hemingway, A., Demorest, H. L., Miller, F. A., Knight, R. T., and Varco, R. L. (1952). *Anesthesiology*, **13**, 455.
Chasmar, R. B., Craston, J. L., Isaacs, G., and Young, A. S. (1951). *J. Sci. Instrum.*, **28**, 206.
Daynes, H. A. (1933). *Gas analysis by measurement of thermal conductivity.* Cambridge University Press.
Dublin, W. B., Boothby, W. M., and Williams, M. M. D. (1940). *Proc. Staff Meet. Mayo Clin.*, **15**, 412.
Epstein, H. G. (1952). *Personal communication.*
Fastie, W. G., and Pfund, A. H. (1947). *H. Opt. Soc. Amer.*, **37**, 762.
Faulconer, A. (1949). *Anesthesiology*, **10**, 1.
Fowler, R. C. (1949). *Rev. Sci. Instr.*, **20**, 175.
Gibson, A. F. (1952). *Proc. Phys. Soc. B.*, **65**, 378.
Gooderham, W. J. (1948). *New methods of gas analysis.* Griffin and Tatlock, Ltd.
Hall, K. D., Garlington, L. N., Nowill, W. K., and Stephen, C. R. (1953). *Anesthesiology*, **14**, 38.
Hunter, J. A., Stacey, R. W., and Hitchcock, F. A. (1949). *Rev. Sci. Instr.*, **20**, 333.
Knipping, H. W. (1924). *Hoppe-Seyl. Z.*, **141**, 1.
Ladenburg, R., and van Voorhuis, C. C. (1935). *Physiol. Rev.*, **43**, 315.
Ledig, P. G., and Lyman, R. S. (1927). *J. clin. Invest.*, **4**, 495.
Lilly, J. C. (1950). in *Methods in Medical Research*, vol. 2, Chicago: Year Book Publishers.
Miller, F. A., Hemingway, A., Nier, A. O., Knight, R. T., Brown, E. B., jnr., and Varco, R. L. (1950). *J. thorac. Surg.*, **20**, 714.
Milner, C. J., and Watts, B. N. (1952). *Research*, **5**, 267.
Pask, E. A. (1952). *Personal communication.*
Pauling, L., Wood, R. E., and Sturdivant, J. H. (1946). *Science*, **103**, 338.
Rein, H. (1940). *Chem. Zbl.*, **1**, 2204.
Ringrose, H. T., Rowling, S. T., and Harbord, R. P. (1950). *Brit. J. Anæsth.*, **22**, 25.
Siri, W. (1947). *Rev. Sci. Instr.*, **18**, 540.
Vengerov, M. L. (1946). *Nature, Lond.*, **158**, 28.
Williams, van. Z. (1948). *Rev. Sci. Instr.*, **19**, 135.

## INDICATIONS FOR AND CONTRAINDICATIONS TO MITRAL VALVOTOMY

In any case of mitral stenosis two factors are responsible for the disability, the narrowing of the valve and the condition of the myocardium. The effects of the rheumatic myocarditis are permanent, demanding increased work of the remaining healthy musculature. The valvular stenosis increases the work of the right ventricle and hence the strain on the musculature. Thus in assessing any case for operation both the stenosis and musculature have to be considered.

Pure mitral stenosis with no history of cardiac failure provides the ideal case for surgery. Coincident regurgitation, if mild and unassociated with gross cardiac enlargement, does not contraindicate surgery because the stenotic element is probably the more severe, and its relief is not usually associated with any marked increase in the regurgitation. Marked regurgitation with a large heart and voluminous left atrium is not benefited by opening the valve further, and such hearts do not stand intracardiac manipulations very well. Aortic stenosis, enough to produce left ventricular preponderance on the E.C.G., will have added strain thrown on the left ventricle by opening the mitral valve further. Aortic regurgitation without a lowered systemic diastolic pressure will tolerate widening of the mitral valve. If systematic hypertension is present, it is unlikely that the mitral stenosis is functionally severe.

Cardiac pain has to be assessed carefully. If associated with a low systemic pressure and a long circulation time then it may well be due to muscle ischæmia and will be

benefited by an increased inlet flow into the left ventricle. Atrial fibrillation is not a contraindication to operation, but indicates that severe myocardial damage is present. The functional result of increasing the left ventricular inflow may be disappointing and the ventricle may not tolerate an unlimited blood intake. The risks of systematic embolism are naturally increased, and a previous history of embolism is of significance. Compression of the carotids by the anæsthetist during the intracardiac manipulations is imperative in such cases. Permanent return to normal rhythm after valvotomy in fibrillating hearts is very rare.

Radiologically visible calcification of the valve is a sign that a really good permanent valve split is doubtful of attainment.

Recent attacks of cardiac failure make the prognosis after operation graver, and desperate attempts to relieve stenosis in failure have a very high mortality.

Pregnancy brings its own particular problems for it is frequently in pregnancy that the first symptoms develop due to the increased blood volume. As a general principle it is probably better to induce an abortion if possible and then do a valvotomy. If, however, this is not possible and the patient can be got out of failure early, then valvotomy can be done between the 16th and 28th week. If failure supervenes after this stage, valvotomy carries a high risk.

Experience has shown that women tolerate the operation much better than do men. This is associated with the fact that men overtax their hearts more severely than do women and failure when it develops can be a more catastrophic phenomenon. Furthermore, the density of the fibrosis about the valve and chordæ with its coincident valvular disorganization and calcification is much more severe in the male than the female. As a result of this the number of successful valvotomies is lower in the male, and recovery

from a cardiac intervention without any significant relief of the stenosis may be beset with myocardial complications.

No particular prognostic value is given by the pulmonary artery or the pulmonary capillary pressure. Patients with high pressures, 80–120 mm. Hg, can do exceptionally well after valvotomy provided the changes are not of too long standing with irreversible arteriolar thickening. Haemosclerosis seems not to be too good a feature. The problem of when to do a mitral valvotomy is not yet decided. In an established case of mitral stenosis should one do a valvotomy before the pulmonary pressures have risen and the myocardium undergone severe strain, or should one wait for the establishment of symptoms? It is probable that as experience accrues, there will be a progressive tendency to do these cases earlier. In childhood, if there are symptoms clearly due to mitral stenosis, then the valve should be treated. Although recurrence of a rheumatic carditis is to be feared below the age of 20, yet incapacitating symptoms call for specific treatment. There are many people walking around without any symptoms of significance from their mitral stenosis, which is yet obviously of functional severity, and who sooner or later are going to be the incapacitated individuals on whom we operate today.

USEFUL REFERENCES

Baker, C., Brock, R. C., and Campbell, M. (1950). *Brit. med. J.*, **1**, 1283.
—— —— and Wood, P. (1952). *Brit. med. J.*, **1**, 1043.
Logan, A., and Turner, R. (1952). *Lancet*, **1**, 1286.
—— —— (1952). *Lancet*, **2**, 593.
—— —— (1953). *Lancet*, **1**, 1007, 1057.

## REFRIGERATION AND HIBERNATION

"THE integrity of any tissue depends upon its receiving an adequate quantitative and qualitative supply of blood."

This quotation from the 1952 Sir Victor Horsley Memorial lecture (Learmonth, 1953) summarizes the fundamental aim of resuscitation before, during and after surgery, viz. to maintain adequate oxygenation of tissues. A number of means are used to achieve this end. The volume of available circulating blood may be increased by transfusion or the use of vasoconstrictor drugs; the Trendelenberg position may be adopted to maintain cerebral blood flow; the amount of oxygen carried in solution in plasma may be augmented by administering pure oxygen. With advances in the use of relatively non-toxic anæsthetic combinations, together with advances in resuscitation, the realm of surgery has greatly increased within the past few decades. Nevertheless, even in the most skilled hands, some patients are still considered unfit for operation, and certain surgically feasible operations are beyond human endurance.

A completely new approach to this whole subject has recently come to the fore, which places emphasis on reducing the oxygen requirements of the body rather than on increasing its carriage to the tissues. Unconsciousness lowers oxygen requirements, but the most drastic reduction compatible with life, which occurs in nature, is seen during the state of hibernation in certain animals. An attempt has been made to produce similar conditions in man, which is termed "artificial" or "elective hibernation". Hypothermia is one of the features of hibernation in animals, and

it has long been known that lowering the temperature of a limb (Allen, 1938) to between 25 and 30°C will not only stop conduction of nerves, but greatly reduce metabolism and oxygen requirements.

The field of cooling, which was limited to operations on limbs (Allen, 1938; Helliwell, 1950), has now been extended to the whole body. It has been shown convincingly that reduction in body temperature is accompanied by a striking decrease in oxygen consumption (Bigelow, 1950; Bigelow et al., 1950; Delorme, 1952). No ill effects have been observed in humans when the rectal temperature has been maintained at 27°C for many hours, but below this ventricular fibrillation is liable to occur (Fay, 1940). Cooling can be achieved by applications of ice or refrigerated blankets (Bigelow, 1950; Bigelow et al., 1950). Delorme (1952) uses extracorporeal cooling, circulating the blood through a refrigerator system outside the body. The application of this technique to humans has recently been described (Delorme, 1953). With all these techniques care must be taken to avoid shivering—the body's natural defence to cold—as this will cause a marked rise in oxygen consumption, together with an increased cardiac output.

Complete paralysis of the autonomic nervous system, and abolition of the shivering response to cold is the aim of the French workers who employ a "liberation cocktail" or "lytic cocktail". The main constituents are phenthiazine derivatives, of which promethazine (Phenergan) is the best known, because of its antihistamine properties (Winter, 1947), and its value in treatment of Parkinsonism (Sigward, 1947). Chloropromethazine (4560 R.P.; Largactil; M. & B. 2378), the most powerful of these drugs, markedly potentiates barbiturates and analgesics (Laborit, Huguenard and Alluame, 1952), has a marked anti-emetic action (Rouchy, 1952) and causes a fall in blood pressure. Laborit and

Huguenard (1952), the pioneers in this form of hibernation, combine these drugs with pethidine and diethazine hydrochloride (Diparcol).

The preparation for operation is commenced several hours before induction of anæsthesia by injection of several doses of the " lytic cocktail ". When the patient is beginning to feel sleepy, cooling is started, the appearance of shivering being an indication for further medication. Very marked reduction in dosage of general anæsthetic agents is observed during anæsthesia. Theatre temperature is kept about 18°C, and hot packs are avoided. The use of ice for cooling has not been adopted by all workers, and even without its use rectal temperatures of 35 to 36°C have been noted at the end of operation (Alluame, 1952). Should the condition of the patient warrant it, hibernation can be continued for several days after operation (Laborit and Huguenard, 1952).

Experimental evidence has been produced showing the ability of this technique to prolong survival time in dogs after bleeding, and their maintenance with an arterial pressure of 35 to 40 mm. Hg without untoward effects (Laborit, Jaulmes and Benitte, 1952). Reports in the literature have been more concerned with the principles and variations of the technique rather than with results obtained in a large series of cases. When these appear one will be better able to decide on its value and the relative merits of simple cooling versus hibernation. Both are complicated techniques which not only require special attention from the medical staff, but add an extra burden on the nurses.

Whatever the technique adopted the principles are the same, and a recent report by Lewis and Taufic (1953) shows some of the possibilities that are opened up. During repair of an atrioseptal defect in a five year old girl whose rectal temperature had been reduced to 28°C, the cardiac inflow

was stopped for 5½ minutes without any untoward effects. Bigler (1951) has reduced by cooling the mortality from operations for cyanotic congenital heart disease from 54 per cent to 14 per cent. With a reduction in cerebral oxygen consumption, controlled hypotension should become a much safer procedure, and the scope of neurosurgical interventions be greatly increased. Patients who at present are considered too ill for major surgery may well come within its scope by having their oxygen consumption reduced to levels which their cardiovascular system can supply. Whereas one now prepares for an operation, in which a sudden severe hæmorrhage is anticipated, by having available several pints of blood, were this patient's metabolism sufficiently reduced the urgency of transfusion would be much less. As in the case quoted above, cardiac surgery should particularly benefit by the possibility of stopping the heart for several minutes without the sequelæ of cerebral symptoms, which would otherwise undoubtedly follow such an event.

REFERENCES

Allen, F. M. (1938). *Surg. Gynec. Obstet.*, **67**, 746.
Alluame, R. (1952). *Anesth. Analg., Paris*, **9**, 261.
Bigelow, W. C. (1950). *Ann. Surg.*, **132**, 849.
—— Lindsay, W. K., Harrison, R. G., Gordon, R. A., and Greenwood, W. F. (1950). *Amer. J. Physiol.*, **160**, 125.
Bigler, J. A. (1951). *J. Amer. med. Ass.*, **146**, 551.
Delorme, E. J. (1952). *Lancet*, **2**, 914.
—— (1953). Paper read to B.M.A. meeting at Cardiff, 15th July.
Fay, T. (1940). *N.Y. St. J. Med.*, **40**, 1351.
Helliwell, P. J. (1950). *Anæsthesia*, **5**, 58.
Laborit, H., and Huguenard, P. (1952). *Pr. méd.*, **60**, 1455.
—— —— and Alluame, R. (1952). *Pr. méd.*, **60**, 206.
—— Jaulmes, C., and Benitte, A. (1952). *Anesth. Analg., Paris*, **9**, 232.
Learmonth, Sir J. (1953). *Brit. med. J.*, **1**, 743.
Lewis, F. J., and Taufic, M. (1953). *Surgery*, **33**, 52.
Rouchy, R. (1952). *Pr. méd.*, **60**, 1324.
Sigward, J. (1947). *Rev. neurol.*, **79**, 776.
Winter, A. C. (1947). *J. Pharmacol.*, **90**, 224.

# ON THE INHALATION OF THE VAPOUR OF ETHER IN SURGICAL OPERATIONS

By JOHN D. SNOW

*(Continued from page 267)*

Except a headache, on one or two occasions, the only unpleasant effect that I have ever seen from the inhalation of ether has been sickness and vomiting, which are only occasional results, and seldom occur except when a meal has been taken just before the ether,—a measure which I prevent when I have the opportunity. It is when, after a meal, the etherization is deep—for instance, in the fourth degree—and continued for some time, that vomiting is most liable to occur. It may take place either during the insensibility or not till after it. The contents of the stomach are in some cases rejected merely by the action of the stomach and the œsophagus, without any accompanying straining, or even the assistance of the respiratory muscles, and without apparent sickness. At other times, both during insensibility and afterwards, the vomiting is accompanied by an expression of sickness in the features, diminished temperature of the surface, with or without sweating, and diminished strength and frequency of the pulse. When sickness occurs it greatly prolongs and increases the insensibility to what the surgeon is doing; even if the consciousness has returned, pain is seldom felt during the sickness. The nausea and vomiting generally subside immediately; but, in two or three instances, have continued till the following day.

The blood that flows in operations under the influence of ether is not much altered in colour. The blood which

spirts from a divided artery is sometimes of its usual vermilion tint, at the very time when the inhalation is going on; frequently, under these circumstances, however, the arterial blood is rather less bright than usual, but the venous blood being at the same time less dark than common, the flow of mixed blood is of the ordinary colour of such blood; and the patient's lips remain unchanged in hue. It has been only when the patient has been holding his breath, or coughing, that I have observed the arterial blood to be of a dark colour; and I consider that those writers who have described it as being, usually or always, of a venous appearance, must have used inhalers that did not allow of a proper supply of air. The blood always coagulates on the floor of the operating theatre, and the black blood which flows during an amputation when the tourniquet is applied, constantly becomes afterwards red on the surface from exposure to the air. (6)

There has not been any considerable secondary hæmorrhage, except in one case, after an amputation; and, therefore, I cannot look upon ether as causing any increased liability to it: nor, indeed, is there anything to prevent every vessel, large enough to require a ligature, being tied at the time of the operation; for there is a good pulse,—a better pulse, indeed, generally than there would be if the operation were performed without the ether.

The following account of the exhibition of the ether, in a few cases, from notes taken just afterwards, is introduced to illustrate the usual effects of it.

CASE A.

A gentleman, aged 49, whose health was much impaired by long illness and residence in the East Indies, had suffered for several years from stricture of the urethra, with fistulous openings in it. No catheter could be introduced, and none of his urine passed the natural way. On April 24, Mr. Liston performed an operation for his relief, part of which consisted in cutting into

the urethra in the perinæum. Mr. Thomas Moreton, Mr. Emanuel Baker, the usual medical attendant of the patient, and Mr. Cadge, were present. The patient having been bandaged as for lithotomy, began to inhale. He breathed steadily and pretty deeply, and became insensible without any excitement or struggling. In four minutes the eyes were turned rather upwards, and there was slight snoring. The operation was now commenced, and it caused no sign of pain. It was concluded in seven minutes, during which he inhaled, at intervals, vapour more diluted than at first. Two or three minutes after the conclusion of the operation, he said a few words incoherently like a drunken man, but was not spoken to, and became silent again. Five minutes after the conclusion of the operation he spoke rationally, saying that he did not begin to feel any stupefying effect from the ether yet. The pulse was but little influenced throughout.

After having been put into bed it was found that there was hæmorrhage, and it became necessary to take up a small artery. He could not be got to lie still enough for it to be seized, so the ether was given again, twenty minutes after he had recovered his consciousness, and thirty-six minutes after the commencement of the first inhalation. In two minutes he was quite insensible, the eyes being turned up, and the respiration rather snoring: he was lifted up, and some cushions placed under him, and he inhaled a little more vapour, and then the artery was secured as he lay quite motionless, and he recovered his consciousness a minute or two afterwards.

℥xiv. of ether were consumed on the first occasion, and ℥vi. on the second. The temperature of the water-bath was 67°; somewhat higher than I now employ.

Being situated at the patient's head, I did not see the operation, and consequently could take no notes of it. It was successful in establishing the natural channel for the urine, and the fistulous openings gradually closed up. The patient had spectral illusions occasionally for a week or two after the operation, but was not alarmed by them, and did not mistake them for realities. He fancied they were caused by the ether; but they most likely depended on his weakly condition, for a time increased by the loss of blood during the operation. I have not heard of anything of the kind after ether in any other case.

### Case B.

On June 19, a lady below the middle age, a patient of Dr. Locock's, who was present, inhaled the ether for an operation, which Mr. Liston performed. Her malady was, in the first instance, a simple serous cyst, at the inner part of the left eyebrow, over the frontal sinus. The walls of the cyst were bony, except at the most prominent point, and here there was only

membrane. The cyst was punctured, and the opening kept patulous by caustic potash. Suppuration followed, and for a time the walls collapsed and the swelling diminished; but afterwards the opening in the bone contracted so much as to prevent the free exit of the pus.

The water-bath being prepared at 64°, the inhalation was commenced, and went on easily and steadily, and insensibility was induced without any struggling. Four minutes after the process was fully commenced, the eyes were turned upwards and towards the right, the pupils being rather contracted, and at this time the operation was begun, without causing a flinch or cry. Mr. Liston made a crucial incision, reflected the flaps, and cleared the bone for the application of the trephine. The inhalation had been left off just after the operation began, and by this time there were evidences of returning sensibility—motion of the eyelids and a little groaning—so the ether was resumed, and Mr. Liston waited half a minute before applying the trephine; at this time the patient was rather rigid from a general contraction of the muscular system, which became relaxed just afterwards, during the concluding part of the operation. A circular piece of bone was removed with a moderate-sized trephine, and a great quantity of pus escaped. The cavity was found to lead to the bottom of the frontal sinus, and some lint was lightly pushed into it. The second inhalation (with the vapour more diluted than in the first, by means of the two-way tap I then used) was continued during the trephining, for I did not know that the operation would be concluded so soon, and was left off just as the operation was concluded. At this time the breathing was inclined to be stertorous, and accompanied by gentle blowing with the lips; but it returned to the natural state in about two minutes. A minute or two afterwards the patient vomited, and she began to recover her consciousness two or three minutes later—about six minutes after the ether had been left off. She spoke in rather an excited way at first, about the operation she had undergone without feeling it, and forgot this conversation; for some minutes afterwards she inquired if the operation was going to begin. When I left, half an hour after the operation, the patient had recovered from the effects of the ether, all but a feeling of sickness, which soon afterwards subsided.

In a short time she was able to wear a plug of India rubber, which kept the soft parts from closing, and the discharge has been since gradually diminishing.

### Case C.

St. George's Hospital, July 22.—Mr. Cæsar Hawkins operated on James Fry, æt. 30, for necrosis of the tibia. The patient inhaled without any impediment, except from a little coughing.

In between three and four minutes he appeared to be established in the third degree. The vapour was now somewhat reduced in strength, and in a minute longer the eyelids were nearly passive; there was an approach to snoring, and the countenance was devoid of expression. The operation was now commenced without the least sign of pain. He had a little dilute vapour occasionally during the operation. The bone was trephined in two places, and the operation completed in five minutes, by the removal of a considerable sequestrum, and he shewed no sign of pain during the performance of it. It was observed, that the pupils of the eyes were sensible to light during the complete state of general insensibility, whilst the lower jaw was hanging down. The pulse was good throughout, but somewhat accelerated. He recovered his faculties soon after he was removed to bed. He had no sequelæ of any kind from the ether, and said that he had the best sleep during the operation that he had had for a long time. ℥ij. of ether were used. He recovered favourably.

CASE D.

Directly after the above operation, Mr. Tatum performed lithotomy on Henry Hemson, æt. 10 years, in good general health. In between two and three minutes after he began to inhale, he was perfectly insensible, the eyelids drooping, and the eyes being rather turned up. The staff was introduced without sign of pain, and he was moved to the bottom of the bed; the ether, in the meantime, having been left off. He inhaled again for about half a minute before the operation began; for he had begun to show signs of sensibility by opening his eyes. The operation was performed without the least sign of pain. I could not see the steps of it, but it was concluded in about two minutes by the extraction of a mulberry calculus, about the size of a kidney bean. He seemed in the third degree during the operation, and not quite so deeply etherized as on the introduction of the staff. He looked about him directly the operation was concluded, and began to sing a school lesson. His face was florid all the time of the inhalation. Mr. Tatum informed me, that the bladder had a tendency to contract, and empty itself by the side of the staff, at the beginning of the operation: this would probably have been prevented by his being etherized a degree further, viz. to the fourth. The little boy quickly recovered.

The following case shews the smallest amount of etherization with which an operation can be satisfactorily performed, as it seemed only just carried to the third degree.

CASE E.

Mr. Keate, assisted by Mr. H. C. Johnson, operated on Sir ——, for two sinuses by the side of the rectum. The patient was rather nervous about the ether, but when he had commenced inhaled very well. In two minutes the eyes were turned quite up, the lids however being kept closed, and they were briskly closed again directly they were lifted up. The face-piece being removed for a moment, the features were observed to be unaltered in expression. At this moment, the expiratory valve was opened a little, to dilute the vapour further; the water in the bath being 64°, and consequently, the patient having been breathing equal parts of air and vapour. At the end of another minute—the third from the commencement of inhalation—there was no further alteration in the patient, except, perhaps, that the eyelids did not close again so briskly on being lifted by the finger; but I observed that Mr. Keate had got a probe introduced into one of the sinuses unknown to me, and with this proof of the patient's insensibility, I requested that the operation might be performed, although otherwise I should have thought the patient scarcely ready for it. During the division of the first sinus the patient held his breath, and moved one hand a little, and stretched out his fingers; and during the division of the second sinus he also moved one foot a little, but not so as to interfere in any way with the operation; and he did not move his body or utter the least sound. The inhalation was discontinued just as the operation was concluded; and half a minute afterwards, as Mr. Keate was thrusting a pledget of lint into the wound, the patient flinched and uttered an angry expression; and directly afterwards he tried to raise himself up from the sofa, but was easily prevented. In less than a minute, he said that he had been in Lancashire disputing with some people; and on Mr. Keate informing him that the operation was concluded, he expressed his surprise and satisfaction, and seemed to have recovered his faculties completely, having been unconscious only three or four minutes altogether. The pulse was counted between the operation and the introduction of the lint, and it was at the rate of 88 in the minute. ʒvijss. of ether were expended.

The attitude and respiration of this patient, and the slight movement of his limbs during the operation, were precisely the same as those of a person suppressing the usual indications of pain, and I have noticed the same thing in some other cases. The dream about the conversation probably occurred at the moment when he first spoke.

In the following case the difficulties in the way of etherization were greater than in any other instance I have

seen, but would have been much lessened, and the patient could have been kept steadier during the operation, if I had had at that time the experience and precaution to recommend a semi-recumbent posture on a table or couch, instead of that of sitting in a common chair.

CASE F.

Miss R. had a tumor of the lower jaw, which commenced fourteen or fifteen years ago, at the symphysis, and extended laterally till it reached nearly the size of the fist, producing great deformity. On May 28, Mr. Liston removed the tumor; Mr. Morton, Mr. Cadge, and some other surgeons, being present and assisting. The patient, who appeared to be between twenty and thirty years of age, was in good general health, but had suffered occasionally from epilepsy. The inhaler was prepared with the water-bath at 65°—the temperature of the water in the room. She was with difficulty got to inhale, even whilst she preserved her consciousness, and in the course of a minute or two, when she passed into the second degree, and had lost the knowledge of where she was, and what was being done, the difficulty was still greater; she sobbed and screamed very much, and stamped with the feet, and pushed the face-piece off with her hands. She was, however, held by those present; and when the face-piece was pushed away it was put on again directly, and in two or three minutes the screaming and all the efforts of a voluntary character ceased, and she passed into the third degree, but became, at the same time, extended in a state of great rigidity, so that she could not be kept seated, and appeared to be in epileptic convulsions with frothing at the mouth. The exhibition of the ether was persevered in, and the patient became suddenly quiet, going into the fourth degree of etherization about five minutes after the inhalation was commenced. She was placed again in the chair; the breathing became slow, deep and regular, and the eyelids were observed to have lost their sensibility. The inhalation having been continued a little longer, was left off about six minutes after it was begun, and the operation was immediately commenced. An incision was made along the inferior edge of the jaw, and a second crossing it over the chin, from below the middle of the free border of the lip; the flaps were dissected off, and the bone exposed: during this part of the operation the patient sat breathing quietly, and not moving or uttering a sound. Mr. Liston then extracted two or three molar teeth with the forceps, and at this time the patient uttered a sound expressive of pain, and struggled. The struggling and demonstrations of pain continued as the bone was being cut through far back on each side. At this time I dipped a small

sponge in ether, and held it to the patient's nostrils, standing behind her (7). Although her mouth was, of course, widely open, she was breathing in some measure by the nostrils, and in a little time became quiet, being apparently perfectly insensible. The bone having been divided, the tumor was depressed, and removed by dividing the mucous membrane and hyoid muscles, the tongue being held forward by a strong ligature drawn through it. The sponge was wetted occasionally, and kept applied to the nostrils, but without the effect of keeping up complete insensibility; for, apparently, the breathing was sometimes performed entirely by the mouth, where, of course, the sponge could not be placed, and the patient struggled again now and then during the tying of the arteries. The pulse was very good, though frequent, at the end of the operation, notwithstanding the loss of blood necessarily attendant on it. She was put into bed ten or twelve minutes after the operation began, and some small arterial branches were secured afterwards. At this time she seemed to have recovered her consciousness (the nature of the operation, however, preventing her from speaking for some time). The wound healed by the first intention, and the patient was able to walk out within a fortnight. She said that she felt nothing of the removal of the tumor, and she was much satisfied with the ether; but for which, indeed, she could not have been prevailed on to submit to the operation. Her appearance was much improved, the deformity caused by the want of the jaw being much less than that which the tumor produced.

Ether contributes other benefits besides preventing the pain. It keeps patients still, who otherwise would not be. I gave it lately, for this object alone, to a child on whom Mr. George Pollock operated for cataract by drilling. The child was perfectly quiet, and the eye and eyelids were quite passive. It had been operated on before, and without the ether would have made all the resistance in its power. In the case related at page 350, Mr. Liston considers that he should have been unable to secure the bleeding vessel without the second application of the ether.

The relaxing effects of ether are much greater than those of the warm-bath and emetics. In the case, No. 40 of the list subsequently to be given, Mr. Tatum reduced a dislocation of the shoulder of ten weeks' duration, in a

muscular man, under the influence of ether, when it was observed, before the traction was exerted, that the muscles were completely relaxed, and the arm much more moveable than before the inhalation. Other cases of reduction of old dislocations, under the effects of ether, have been related in the medical journals, and also cases in which the surgeon was enabled, by means of it, to reduce strangulated herniæ with the taxis, where, otherwise, an operation would have been required. In Case 7 of the second list, farther on, the ether superseded one of the most difficult operations in surgery, and enabled Mr. Liston to get a catheter into the bladder without using the knife.

The real value of the inhalation of ether in surgical operations must be mainly determined by the ultimate success of the cases in which it is practised. A surgical operation is a necessary evil, submitted to for the advantage of a greater good which is expected to result from it; and if the ether added at all to the danger of the operation, or diminished in any way the full advantages to be derived from the operation, it would be the surgeon's duty to recommend his patient to submit to the pain, excruciating as it often would be to him, and distressing to those who have to witness it. It is very evident, *a priori*, that an agent which so alters the circumstances of the patient, cannot be without its effects on the ultimate results of capital operations; and since severe pain generally exerts a deleterious influence on the economy, and the use of ether in thousands of trivial operations has shewn it, when properly managed, to be attended, either with no danger, or the least conceivable amount of it, it seems to follow that etherization must lessen the danger of serious operations, unless we think (with one or two renowned doubters, who seem to look upon a surgical operation as a natural process, in which the

pain plays some essential part), that the sufferings of the patient in some way aid his recovery, instead of being deleterious to him. However, the proper and philosophical course to pursue, as soon as we have the opportunity, and one generally followed in medical science in similar instances, is impartially to examine the results, disregarding what we might beforehand expect.

In order to contribute what I can towards such an examination of the influence of ether over the results of surgical practice, I subjoin a list of all the operations in which I have administered the ether in St. George's and University College Hospitals. In the very few cases which ended unfavourably, and in some of the others, I have added notes, which I have copied from the Hospital case-books. The operations down to about Midsummer were briefly but correctly reported as far as related to the ether, in the Lancet, from time to time. In no case in which I have given the ether did the patient know anything of the operation, except, two or three times, some trivial part of it, such as tying an additional small artery after the inhalation had been discontinued. And it may be remarked, that the constant success with which ether is capable of being employed, is one of its greatest advantages; and, that the patient may have the full benefit of this discovery, he should not only be spared the pain, but also the anticipation of it, often so depressing to his powers, and should feel confident, from the time the operation is proposed, that he will suffer no pain, and be exposed to no danger. In most of the following cases the patients have looked forward to the operation merely as the time when they would get rid of a painful joint, or some other troublesome disease; and this has been generally the case also in private practice.

## LIST OF OPERATIONS WITH ETHER AT ST. GEORGE'S HOSPITAL

1. January 28, Mr. Cæsar Hawkins removed dead bone from the interior of the tibia of William Daphne, aged 6 years.—Recovered. Left the hospital March 10.

2. On the same day Mr. Cutler performed amputation of the thigh on the patient whose case is subjoined:—

"William Cowen, aged 23, a stout healthy-looking groom, was admitted into the Oxford Ward, Dec. 1, 1846, having a short time previously been thrown with great violence by a horse. On the interior and anterior surface of the right thigh, about its middle, a wound in two lines, meeting at a right angle, and three inches long each way, penetrated the muscles in its whole extent, and exposed the bone. The vessels were almost laid bare, but the hæmorrhage was slight. The right leg was fractured at its lower third, with much comminution. Four days after admission, inflammation of an erysipelatous character appeared round the wound, and crept up the limb during the following eight days. Considerable irritative fever and depression gradually supervened, and increased as the discharge became more profuse and ill-conditioned. 29th. A very large quantity of foul pus was let out by an incision on the external surface of the thigh, and on the 27th of January, 1847, the knee-joint presented every appearance of being distended with pus. The patient was in such a state of extreme depression, as to render any motion, or attempt at examination, productive of most alarming symptoms; and a phthisical cough troubled him. Such was the state of the case, when, at a consultation of the surgeons, it was determined to give him the chance of an operation under the influence of ether. On Jan. 28, therefore, the vapour was administered by Dr. Snow. In less than three minutes perfect insensibility was produced, and it was continued whilst the patient (who was in too weakly a state to bear removal to the operating table) was drawn to the foot of the bed, and amputation of the thigh performed, consciousness only returning during the washing of the stump, which was productive of pain. He said that he felt nothing of the operation: no sickness or headache followed. He passed an excellent night, free from the usual startings of the stump; was in good spirits next day, and smiled when addressed. On the twelfth day he was up. From this time his health slowly and gradually improved: the cough, at all events, did not increase. The stump granulated, without an unfavourable symptom, till the beginning of April, when some inflammation about it, and slight fever, ended in the formation of an abscess. He was discharged May 12, to go into the country, the stump being nearly healed, and small sores only remaining of the ulcers.

"He was re-admitted to the hospital this autumn, almost destitute, much emaciated, and suffering with cough and haemoptysis.

He has derived considerable benefit from the treatment, and will shortly be discharged."—ADOLPHUS J. GEE.

3. On the same day, also, Mr. Tatum removed a large fatty tumor from the shoulder of Francis Lewis, aged 42; a man of colour.—Recovered. Left the hospital May 26.

4. Feb. 4, Mr. Cæsar Hawkins operated for necrosis of the tibia, on a young woman—(I neglected to take down the name and age in this and one or two other cases).—Recovered, and left the hospital.

5. On the same day, Mr. Cutler performed the operation for fistula in ano, in a middle-aged man.—Cured.

6. On the same day, also, Mr. Tatum amputated the breast of Caroline H——, aged 32 (married), for scirrhus.—Recovered. Left the hospital March 3.

7. Feb. 11, Mr. Cutler performed lithotomy on Wm. Doran, aged 4 years.—Recovered without an unfavourable symptom, and left the hospital March 3.

8. The same day, Mr. Henry Charles Johnson amputated the breast of Ellen A——, aged 40 (widow), for scirrhus. This patient was suffering from bronchitis at the time of the operation, and the ether caused a good deal of coughing, and was left off somewhat prematurely on this account, and the operation performed. There was some struggling, but the patient talked during the operation about matters quite unconnected with it, and said afterwards that she felt no pain. Her cough was relieved for the first two or three days after the operation.—She recovered favourably, and left March 10.

9. Feb. 25, Mr. Cutler removed the right mamma of Mary F——, a cook, aged 54, affected with scirrhus tumor.—Recovered. Left on March 31.

10. The same day, Mr. Cutler amputated the thigh of Thomas Hood, aged 13 years, for long-standing scrofulous disease of the knee-joint, by which he was much debilitated.—Recovered. Left April 7.

11. On Feb. 25, also, Mr. Henry James Johnson amputated the thigh of Anne Atkinson, æt. 11:—

"This little girl was admitted August 19, 1846, under the care of Mr. Keate, in a weakly, emaciated condition, with necrosis and caries of the left leg, reported of a month's standing, and to have commenced suddenly, with pain and fever. The entire middle third of the tibia appeared to be diseased, and several sinuous openings existed in this situation, leading to necrosed and carious bone. The tenderness was excessive.

"Dec. 24, 1846, the health having improved somewhat under treatment, numerous small pieces of dead bone were removed by operation; no immediate ill effects followed, and the wound continued in a tolerably healthy condition till about the second week in January, 1847, when it was attacked by erysipelas, which in the

course of a week extended up the thigh, and then faded rapidly, leaving the patient much reduced, and the knee-joint, and the thigh immediately above it, red, tumid, and painful. Thus the case continued, the patient getting weaker, and the abscesses increasing up the thigh. As the great tenderness of the parts, and the state of the patient, precluded every attempt to examine the state of the limb in the usual manner, the ether vapour was administered by Dr. Snow's apparatus, with perfect success, and, while the patient continued in a state of unconsciousness, the condition of the parts was ascertained sufficiently for the surgeons in consultation to determine on amputation.

"Feb. 25. The thigh was removed at its middle third by the flap operation, the ether vapour being again inhaled with the same success as before. On examining the limb it was found that the abscess was situated in the ham, and amongst the muscles of the thigh, having a very slight connection with the joint, which was, for the most part, healthy. No sickness or headache followed. The patient had a sound night's rest, undisturbed by starting of the stump, and the following day said she was much easier than she had been for a long time, and did not know till 9 this morning that the limb had been removed. She never gained strength, however: there was scarcely an attempt at healing, and the bone was exposed. She sank gradually, and died March 5."—ADOLPHUS J. GEE.

*Examination, eleven hours after death.*

"*General Appearances.*—The body was a good deal emaciated. There were superficial sloughs on the sacrum, trochanters, and crests of the ileum. The left leg had been amputated above the knee: the extremity of the bone was exposed, and the stump in an unhealthy condition. The right foot was œdematous.

"*Thorax.*—There were some recent adhesions of the pleura on the left side, chiefly at the outer and back part of the chest. Some shreds of lymph were adhering to the surface of the lungs, but there was no fluid in the cavity of the pleura. The anterior portions of the left lung were healthy and crepitant, but the posterior and lower portions were much congested, consolidated, and contained numerous secondary abscesses, in various states of suppuration and of various sizes; the seat of the abscesses being chiefly near the surface of the lung. The right lung was in a similar condition to the left, containing various abscesses at its posterior part.

"The heart was healthy, but flaccid; the blood particularly fluid. There were some loose fibrinous coagula in the cavities.

"*Abdomen.*—The viscera were all healthy.

"*Left lower extremity.*—The extremity of the bone was denuded of periosteum to about the extent of half an inch, and the bone itself of a dark colour. The wound was foul at the posterior part, but in front had apparently been commencing to heal. Liga-

tures were found attached to the femoral vein and artery, the wound around being both foul and unhealthy. The periosteum was easily pulled off the bone for some distance above the sawn extremity. On opening the femoral vein it was found to be filled with thin darkish-coloured pus as high as the bifurcation of the abdominal cava; but the lining membrane gave no indication of inflammation of the coats of the vein."—GEO. POLLOCK.

12. March 4, Mr. Tatum amputated the leg of a man, much reduced by disease of the ankle-joint.—Recovered.

13. The same day, Mr. Tatum also amputated the leg of James Thomas, aged 17, for strumous disease of the foot.—Recovered. Left May 12.

14. March 11, Mr. Cutler removed the great toe of Henry Bunn, aged 14, together with its metatarsal bone, for strumous disease of the bones.—Recovered, and left the hospital.

15. The same day, Mr. Tatum amputated the thigh of James Stanmore, aged 15.

"He was admitted Feb. 24. Inflammation of the leg began twenty-three weeks before his admission, and matter was let out from the knee about three months before his admission. When admitted he was much emaciated, and very pale. Pulse very quick, weak, and sharp. Tongue clean and moist. The natural shape of the extremity was lost, and it was at least double its natural size. Several incisions in various parts of the leg, and two or three fistulous openings on the knee, were discharging tolerably healthy pus, and the skin round the incisions was thickened and tuberculated. The thigh and left nates were highly œdematous, and there was a large excavated bed-sore over the sacrum. Shortly after admission an attack of shivering was followed by increased swelling, and a blush of erysipelas from the hip to the knee. His appetite became worse, and his debility increased. March 8, these symptoms subsided, and on the 11th amputation was performed. As the patient could not be moved, owing to the excessive tenderness of the part, and his weakly condition, he was brought into the theatre on the bed. After inhaling the vapour of ether for two or three minutes by Dr. Snow's apparatus, he fell into a state of perfect insensibility, was drawn to the edge of the bed, and the operation performed, without his evincing any sign of consciousness. The parts cut through were highly œdematous, and the muscles pale and flabby. Some sickness occurred on his return to the ward, but he slept well, with very little starting; he suffered, however, more from that cause on the following day, but was quite easy on the 13th, on which day the stump was dressed for the first time. No union had taken place—suppuration had commenced. The case progressed favourably till the 19th (the eighth day after the operation), when, after suffering much pain during the night in the stump—relieved in the morning by dressing—the patient was seized, about 1 P.M., with a severe

rigor, followed by a slight hot stage. Pulse frequent, and very weak; tongue clean and pale. From this time he sank rapidly, several rigors occurring daily. There were bilious vomiting and stools. Latterly he was free from all local pain. The discharge from the wound was profuse and fœtid, and the bone protruded slightly, but the stump in other respects looked well. There was slight wandering delirium the last two days only. He died on the 27th."—ADOLPHUS J. GEE.

*Examination, fifty-seven hours after death.*

"*General appearances.*—The body was much emaciated. The pelvis was a good deal distorted, from lying in bed. The left leg had been amputated recently above the knee, and the wound was still open. There was a considerable bed-sore on the sacrum.

"*Thorax.*—There were some old pleuritic adhesions on the left side of the chest. There was considerable inflammation and softening of the lower and back part of the left lung, with several secondry abscesses. There were old adhesions of the pleura on the right side, and several secondary abscesses in the back part of the lower lobe of the right lung. The heart was healthy, and contained some loose fibrinous coagula.

"*Abdomen.*—There were some adhesions of the peritoneum at the upper surface of the liver. The viscera were generally healthy. There was a small quantity of pus in front of the left hip-joint, apparently in the substance of one of the inguinal glands. The glands in the groin were generally enlarged, and of a black colour. The cellular sheath of the femoral vessels was much condensed, and very much firmer than usual. The femoral vein was blocked up with pus and purulent coagula, and the interior of the vessel was of a black colour. This inflamed condition extended from the end of the stump to the interior of the pelvis. The end of the bone was protruding from the stump, and quite exposed. There was a large quantity of matter burrowing up, in the back part of the stump, in the substance of the muscles. New bone had been recently thrown out on the lower part of the surface of the bone. The head of the femur was dislocated on the dorsum of the ileum, and perfect, though recent, anchylosis had taken place between the two bones. The acetabulum was filled with recent darkish-coloured lymph, and almost all traces of cartilage had disappeared. The bones forming the joint, &c., were softened, and readily cut with the knife."—GEO. POLLOCK.

16. March 18, Mr. Keate amputated the leg of Samuel Richards, aged 9, a boy of colour, for disease of the ankle-joint.—Recovered.

17. The same day, Mr. Cæsar Hawkins amputated the fore-arm of Henry Knight, aged 45, for disease of the wrist-joint.—Recovered.

18. The same day, also, Mr. Henry Charles Johnson amputated the breast of Mary A——, aged 48, married, for scirrhus.—Recovered, Left the hospital April 14.

19. April 1, Mr. Cæsar Hawkins removed a fatty tumor from the shoulder of Mary Brindle, aged 48, a cook.—Recovered. Left April 21.

20. The same day, Mr. Cutler amputated the leg of George Stamper, aged 23, who was admitted March 25, with disease of the ankle-joint of five years' standing. There is a scar on the left side of the sternum, from which a piece of dead bone separated five years ago. He has had a cough during the last winter, and Mr. Gee's notes contain the following:—"Dr. Fuller examined his chest, and found that there was some condensation at the upper part of the right lung." On examining the limb after the amputation, the ankle-joint was found to be destroyed; about half an inch of the inferior articulating extremity of the tibia being perfectly necrosed and loose, the articulating surface of the astragalus deprived of its cartilage, and nearly all the bones of the foot softened. His cough was relieved the first two days after the operation, and still more so as his health improved. The stump healed by granulation, and he left on May 5.

21. April 8, Mr. Cæsar Hawkins amputated the thigh of Thomas Witcher, aged 18, for disease of the knee-joint.—Recovered. Left on May 19.

22. The same day, Mr. Cæsar Hawkins also amputated the forearm of George Richardson, aged 48, for severe disease of the wrist-joint. This patient was in a very bad state of health, and suspected to have disease of the lungs.—Recovered. Left May 19.

23. The same day, Mr. H. C. Johnson operated for hare-lip on a little girl apparently about twelve years old—an out-patient. Cured.

24. April 15, Mr. Cæsar Hawkins operated on Mary Andrews, aged 57, by needles and ligatures, for a vascular tumor of the lip. Cured. Left May 15.

25. Same day, Mr. Cæsar Hawkins operated for necrosis of the metatarsus, on Caroline Collins, aged 7.—Recovered.

26. April 29, Mr. Cutler amputated the thigh of Ann Coston, a servant, aged 19. This patient had been subject to inflammation of the knee-joint from her childhood, and from Midsummer to Christmas last year she was in the hospital with symptoms of ulceration of the cartilages, but went out much relieved. She was re-admitted on March 17. The pain had recurred about a month after leaving the hospital, and had been getting worse ever since. The pain and tenderness still increasing, and being accompanied with starting of the limb again, and her general health being good, amputation was performed by a circular incision. The cartilages were found to be extensively destroyed. Two hours after the operation she was comfortable—the pulse quiet and regular, the stump oozing freely. An hour later, there was sudden hæmorrhage from the wound in a jet. The stump was opened, and was found full of coagula, which Mr. Cutler removed, and secured two vessels. There was not much

blood lost, and there was no return of the hæmorrhage. She suffered from starting in the stump and pain in the abdomen, the first two days. These symptoms subsided; but on May the 3rd she became worse, and was attacked with sloughing phagedena of the stump.* On the 5th the ulceration ceased, after having exposed the shaft of the bone, and by the 16th she was much improved, having a good appetite, and the stump granulating. She went on improving till the 26th, being then upon crutches; but the following day she was again attacked with sloughing phagedena, with much pain and fever, and a brown tongue. On the 30th the ulceration ceased, but in a day or two began to extend again. On the 4th of June, however, the complaint seemed to be finally arrested, and from this time she steadily improved, and an excellent stump was formed by granulation, and contraction of the skin over it. She was discharged convalescent on August 11.

27. The same day, Mr. Tatum amputated the thigh of Maria Lindley, aged 15, for disease of the knee-joint. She went on favourably, and on the 26th of May was so far recovered as to leave the hospital with the stump nearly healed, but she returned again in a few days with sloughing phagedena. The flaps sloughed off, leaving the bone bare, and she was extremely ill for some time, but recovered, and left the hospital with a good stump.

28. May 6. Mr. Keate amputated the thigh of George Missen, a labourer, aged 26, for extensive and long-standing disease of the knee-joint. June 12, discharged convalescent—going into the country.

29. May 13. Mr. Cæsar Hawkins performed an operation for necrosis of the humerus, on George Uren, aged 16. The operation necessarily lasted a long time, but the boy was perfectly insensible throughout its duration. The wound healed extremely well. In a week the patient was going about the ward, and was soon quite well.

30. May 20. Mr. Keate operated on Sarah Perrott, aged 21, for necrosis of the tibia. Recovered.

31. Same day, Mr. Cæsar Hawkins removed an epulis from the mouth of George Patient, aged 34. Recovered. Left June 2.

32. Same day, also, Mr. Tatum amputated the leg of William Walsh, aged 22, much emaciated and very feeble, for scrofulous disease of the ankle. Recovered. Left the hospital July 7.

33. May 27. Mr. Cutler operated on Alfred Frith, aged 18, for necrosis of the tibia. Was soon well.

* The wounds resulting from the operations had healed well—in a great measure by the first intention—till about this period, when sloughing phagedena being prevalent in the hospital (and apparently in the neighbourhood, for some patients came in with it) it attacked some of them. It did not, however, commence first amongst the subjects of operation. See a clinical lecture on this subject, by Mr. Hawkins, in the Medical Gazette.

34. June 3. Mr. Tatum amputated the thigh of Ellen Benson, aged 14, for disease of the knee-joint of long duration: the cartilages were destroyed. On the 8th, she was going on favourably, but soon after this was attacked with sloughing phagedæna. The end of the bone had to be sawn off, and she remained for a long time in a very precarious state, with hectic and diarrhœa. After a time, however, her health improved somewhat, and she left the hospital on Aug. 4, to go into the country. On Sept. 14th, the nurse had heard from her friends that she was still improving.

35. June 10. Mr. Cæsar Hawkins removed a malignant tumor of the testis from Thomas Wild, aged 46. "This man was admitted May 5, with enlargement of the left testis, which commenced five months previously. It was about the size of an ostrich's egg, irregularly pyriform, dense, and hard, with some fluid in the tunica vaginalis above it. There was no pain, but some tenderness. The scrotal veins were not enlarged; the cord was apparently healthy. The epidymis and testis were not distinguishable. In the left breast, also, there was a tumor about the size of a small chestnut, not very hard, having an irregular corded surface, very moveable, unattached to the skin or nipple, and neither tender nor painful. The patient was thin, and had an unhealthy aspect. The appetite was bad, and pulse weak. His health improved considerably, and the tenderness diminished soon after admission.—10th. About an ounce of yellow albuminous fluid was let out of the tunica vaginalis by a grooved needle, and a course of mercury and sarsaparilla was commenced, but discontinued on the 30th, as the testicle increased in size under it.—June 10th. Castration was performed: the patient being placed under the influence of ether was perfectly insensible to the operation. The tumor removed was about five inches long, and two and a half in diameter. A section through it presented a purplish hue; it was composed of a soft pulpy substance, and much dark red fluid could be squeezed out of it. The centre was somewhat harder, yellowish, and intersected by white bands. No trace of the healthy structure of the testis could be discovered. The tunica vaginalis at the upper part contained about an ounce of yellow fluid, and had the disease projecting into it. No headache or any other symptom followed the etherization, and for the six succeeding days the case progressed well.—15th. Some slight pain under the right scapula was complained of, but on the 17th, after having the previous evening suffered from slight chilliness, he was seized with some pain, unattended by tenderness, in the right ilium and lumbar regions, and frequent bilious vomiting and diarrhœa. The countenance was yellow, haggard, and anxious. Pulse accelerated, and tongue rather dry.—18th. All these symptoms continued, and there was tenderness on the right side of the abdomen, and no water having been passed for twelve hours, about half a pint loaded with lithates was drawn off.—19th. There was some swelling and tympanitis at the

upper part of the abdomen, with very little pain. At 9 P.M. he died. For the last twenty-four hours the sickness was almost incessant; a black grumous matter being vomited."—ADOLPHUS J. GEE.

*Examination, sixteen hours and a half after death.*

"*General Appearances.*—The body was well formed, but emaciated. There was a hard swelling, about the size of a small egg, felt in the left breast, which, on being cut into, proved to be simple enlargement of the gland.

" *Thorax.*—In the cavity of the left pleura there was some thin bloody serum. The left lung was slightly congested, and filled with frothy serum. On the anterior surface of the middle lobe there was an encephaloid deposit of about the size of a nutmeg. There were two similar deposits in the middle lobe of the right lung. The heart was quite healthy.

" *Abdomen.*—There was a considerable quantity of pus in the peritoneal cavity. The intestines were glued together by bands of lymph. The vessels of the intestines were injected. There were several small deposits of a malignant nature on the lower part of the ileum. There was a large encephaloid tumor, of about the size of an orange, lying in the third and fourth lumbar vertebræ. The vessels were quite free, and lying behind it. All the viscera were healthy."—Entered by Mr. Mackin, house-surgeon. GEO. POLLOCK.

36. The same day, Mr. Cutler amputated the middle finger of John Felton, aged 63, a countryman.—Cured. Left the hospital July 6.

37. June 17, Mr. Cæsar Hawkins amputated the thumb of Joseph Croker, aged 20, on account of scrofulous disease of the bones.—Recovered.

38. June 24, Mr. Cutler amputated the leg of John Gale, aged 19, for disease of the ankle-joint of six months' standing, having first lanced an abscess in it whilst he was insensible, and ascertained with the probe that the joint was extensively diseased.—Recovered. Left the hospital July 28.

39. The same day, Mr. Tatum operated on James Walters, aged 14, for necrosis of the tibia.—Recovered.

40. The same day, Mr. Tatum also reduced a dislocation of the shoulder, with the pullies, of ten weeks' standing, in Richard Rowlings, aged 31.—Recovered the proper use of the joint.

41. July 1, Mr. Cutler amputated the thigh of Mary Lessiter, aged 26, for extensive and long-standing disease of the knee, by which she was reduced to a very feeble state.—Improved from the time of the operation, and left the hospital August 24, in good health.

42. The same day, Mr. Cutler also amputated the leg of Henry Stanton, aged 44:—

" This patient, a stout hale man of temperate habits, was admitted

June 9, with an irregularly-shaped, dark, and very painful ulcer over the tibia, about the middle of the left leg; the limb below it was indurated and swelled, and the ankle-joint was fixed. The ulcer was of thirty years' standing, and proceeded from a severe lacerated wound, caused by the shaft of a gig, exposing the bone, which frequently exfoliated. The ulcer remaining had been productive of much suffering, and continued about the size of the palm of the hand, till a short time before admission, when it rapidly increased a third. The ulceration having ceased under the treatment, on the 1st of July amputation was performed, by the earnest desire of the patient. The operation was a long one, owing to the difficulty experienced in securing some of the vessels. The patient having inhaled ether, was insensible to the early part of it, but recovered consciousness during the application of the ligatures, the inhalation being discontinued, [under an impression that the operation was on the point of being concluded]. On examination, the tibia, immediately under the ulcer, was found to be thickened, carious superficially, its compact tissue very hard, and the cancelli softened. Considerable pain in the loins, to which it appeared he was subject, supervened shortly after the operation, and was the cause of a restless night. The following morning it still continued, and the urine was alkaline, but clear. The tongue was moist; pulse weak and regular. A draught of opium and ether relieved the pain, but at 9 A.M. of the 3d, a rigor, followed by heat and sweating, occurred, and a fatal train of symptoms rapidly appeared.—5th. The stump looked somewhat sloughy.—6th. The whole surface of it was affected with phagedæna. The urine was again acid, pulse 120, very weak, tongue clean and rather dry, and he sweated freely. About 2 P.M. on the 7th, he was seized with a second rigor, from which he did not recover: the lips continued pale, skin cool, and pulse imperceptible, and he died 6½ P.M."—ADOLPHUS J. GEE.

*Examination, twenty hours after death.*

"*General Appearances.*—The body was rather fat, and its surface exsanguine. The left leg had been amputated below the knee-joint. The stump was sloughy on its surface, with no evidence of granulation; above the wound the leg was rather œdematous.

"*Thorax.*—The lungs were crepitant and healthy throughout. The cavity of the pericardium contained a very small quantity of blood-stained serum. The heart was rather large and flabby, and the structure soft, and lacerable without difficulty: there was much fat on its surface. The left ventricle was somewhat dilated, the walls not hypertrophied, but much fat mixed up with the muscular structure. The aortic valves were much thickened, and two of them so much affected and contracted, that they together were about the size of a healthy one; almost cartilaginous in structure, but free from atheroma. The right ventricle was considerably dilated, and

its walls were extremely thin, in some places having very little muscular structure between the external and internal membranes, and the muscular structure throughout having a considerable proportion of fat mixed with it: the inner surface generally was blood-stained. The cavities contained some fibrinous and some black coagula.

"*Abdomen.*—The viscera were healthy.

"There was no inflammation of the femoral or iliac veins."—GEO. POLLOCK.

43. July 8, Mr. Henry Charles Johnson removed three encysted tumors from the scalp of a middle-aged woman (an out-patient).—Recovered.

44. July 22, Mr. Cæsar Hawkins operated on James Fry, aged 30, for necrosis of the tibia.—Recovered. (This case and the next are described at pp. 352 and 353.)

45. The same day, Mr. Tatum performed lithotomy on Henry Hemson, aged 10 years.—Recovered without an untoward symptom.

46. August 5, Mr. Cæsar Hawkins removed four loose cartilages (one of them ossified, and as big as a seed of nux vomica) from the knee-joint of Francis Clayton, aged 27, a countryman, who had been troubled with the largest one eleven years. The operation was performed by getting the foreign bodies into a suitable position under the skin, and cutting directly upon them, and pressing them out.—Recovered. Left the hospital Sept. 1.

47. August 12, Mr. H. Charles Johnson operated for the removal of an old and unsightly cicatrix from the lower lip of Christopher Woodward, aged 25.—Recovered.

48. August 19, Mr. Tatum performed an operation on Betsy Power, aged 17, for necrosis of the tibia.—Sept. 16. In good health, and wound fast filling up by granulations.

49. August 26, Mr. Cutler removed a scirrhous tumor situated in the cellular tissue, just above the right mammary gland, of Diana Jones, spinster, aged 49.—Recovered, and left the hospital Sept. 15.

50. Sept. 2, Mr. Henry James Johnson removed a scirrhous tumor of the mamma of Martha F——, aged 36.—Sept. 16. Going on well, filling up by granulation; a good deal of skin was affected, and had to be removed.

51. The same day, Mr. Henry Charles Johnson removed a scirrhous tumor from the breast of Sarah H——, aged 45.—Sept. 16. Healing favourably.

52. The same day, Mr. H. C. Johnson also opened a deep-seated abscess of the mamma of Elizabeth R——, aged 40. She was placed on the operating table, and had the ether, as it was surmised that a larger operation might be found necessary.—Sept. 16. Nearly well.

In addition to the above operations, Mr. T. B. Bumpsted, house-surgeon at the hospital, has administered the ether in four cases of

emergency, with the same kind of apparatus. One was a case of compound comminuted fracture of the thigh, occurring to John Lidgate, aged 26, on the 27th of July, in which Mr. H. Charles Johnson amputated high up, just below the trochanters. Another operation was an amputation of the arm, performed also by Mr. H. C. Johnson, on account of the brachial artery being opened by ulceration a few days subsequent to an accident to the elbow. The two remaining operations were for strangulated femoral hernia in women.—All the four patients recovered.

The following are the operations in which I have administered ether in University College Hospital:—

1. May 3, Mr. Liston performed lithotomy on Joseph Rice, aged 28, who had come from Australia to have the operation done. A ligature had to be applied to an artery in the anterior part of the wound—apparently an irregularly distributed branch of the pudic: the calculus was a globular mulberry one. The patient went on well. After the 26th, no more urine passed by the wound.—Discharged, cured, June 6.

2. The same day, Mr. Liston also removed a large encysted tumor, in a sloughing state, from the scalp of a woman, aged 72.—Recovered.

3. June 4, Mr. Liston performed excision of the elbow-joint of John Harris, aged 37, on account of extensive disease of the joint and surrounding parts, following an accident. The soft parts having been dissected off, the whole of the articulating part of the condyles of the humerus, the head of the radius, and the ulna (as low down as the coronoid process), were removed. Went on favourably.—Discharged, cured, July 27. Uses the hand, and has considerable power of flexion and extension.

4. June 5, Mr. Quain amputated the thigh of Charles P——, aged 12, for disease of the knee-joint of some years' standing. Antero-posterior flaps were made: pus flowed at the first incision, showing that the abscess extended up the thigh. The circular incisions were made so as to exclude the abscess.—Recovered favourably. Discharged, cured, in August.

5. June 7, Mr. Liston performed lithotomy on John Atkin, aged 70, in whom the presence of stone had been diagnosed eight years previously. A few hours after the operation there was some hæmorrhage from the bladder through the elastic tube, the urine passing by the side of the tube; but it ceased of itself. He suffered from pain and feverishness for a few days, but afterwards went on favourably, and left well on August 17.

6. The same day, Mr. Liston amputated the index finger of Mary Mills, aged 25, at the metacarpo-phalangeal articulation, for spina ventosa of the proximal phalanx.—Discharged, cured, June 20.

7. June 18. Mr. Liston introduced a catheter for John Willis, aged 42, who had stricture of the urethra, caused by an injury twelve years ago. He passed his urine in a very small stream for the last three years, and latterly only by drops, and no catheter could be introduced. Mr. Liston intended to divide the stricture by cutting in the middle line of the perinæum, but when the patient was got fully under the influence of the ether in the fourth degree, a No. 1 catheter was introduced right into the bladder through the stricture, and the intended operation was not required. The catheter was tied, to retain it in the bladder. On the 23d it was removed, and No. 2 passed, and then No. 3, which was allowed to remain two hours: he could now pass his urine in a moderately-sized stream. He went on well till July 22, when he had an attack of suppression of urine. He recovered from this, and went out cured on the 27th of July, being able to pass his urine in a good stream.

8. June 26. Mr. Quain amputated the index finger of Joseph Phillips, aged 70, at its metacarpo-phalangeal articulation, for necrosis of the bones of the phalanges.—Became out-patient July 12: was cured.

9. The same day, Mr. Quain also amputated the leg of Robert Gray, aged 54, below the calf, for disease of the tarsus, caused by an injury two years and a half before. "There was considerable difficulty in securing the peroneal artery, which was retracted beneath the fibula. He was insensible during the operation, but owing to the length of time occupied in securing the arteries, the effect of the ether had almost passed off." The stump healed very well, but a few days after the operation, diarrhœa, to which he had been subject for two years, set in, and could not be permanently checked, and he died August 14. After death the mucous surface of the large intestine was found to be abraded at intervals in its whole length. It was of a dark slate colour in the greater part, and where the slate colour was wanting, the vessels were injected. The gut was also much thickened. The small intestines were healthy, and the other viscera nearly natural.

10. July 2. Mr. Liston amputated the thigh of Belinda Norris, aged 15, for disease of the knee-joint of four years' duration. She was in a state of great debility, but her health improved from the day of the operation, and she was discharged, cured, in August.

11. The same day, Mr. Liston performed an operation on Emily Cannon, aged 5½ years, for scrofulous disease of the metatarsal bone of the great toe, removing it at the metatarso-tarsal joint.—Progressed favourably, and was made an out-patient in August.

12. The same day Mr. Liston reduced a recent dislocation backwards of the elbow, in a boy (an out-patient).—Cured.

13. July 9. (In a private ward of the hospital), Mr. Liston operated for prolapsus ani on A. H., a woman aged 27, removing some hæmorrhoids and folds of relaxed mucous membrane.—Cured.

14. The same day, Mr. Liston extracted a polypus from the nose of a young female.—Cured.

15. The same day, (in the operating theatre), Mr. Liston removed a diseased testicle from Joseuh B., aged 47.—Discharged cured, August 14.

16. The same day, Mr. Liston performed lithotomy on Charles Butler, aged 10½ years, removing a mulberry calculus about the size of a bean. The child got rapidly well.

17. The same day, Mr. Liston amputated the ring finger of Sarah Powell, aged 14, at its metacarpo-phalangeal articulation, for disease of its first phalanx. Made out-patient, July 13.

18. July 23. Mr. Liston amputated the arm of George Aliston, aged 26. The arm had been affected with scrofulous disease for twenty years. It commenced in the elbow-joint, and extended to the fore-arm, hand, and fingers. The limb was much swollen, and had several ulcers and fistulous openings in it. It was amputated by antero-posterior flaps, rather above the middle of the humerus. The patient, who was in a state of great debility from the disease, went on favourably till the 27th, when erysipelas attacked the stump. On the 28th, erysipelas attacked the face also; it subsided in a day or two, but the debility continued, with low muttering delirium, and he died August 1st.

*Autopsy, twenty-six hours after death.*

Body much emaciated. Old adhesions of the right pleuræ. Puckering of the apices of both lungs, and a cavity the size of a pea in the apex of the right one. Heart and other viscera healthy. Stump sloughy; flaps partly adherent, but loose from bone, which was denuded of periosteum.

19. July 31. Mr. Quain amputated the thigh of James Godden, aged 27, for disease of the knee-joint of twenty years' standing. He was extremely ill and feeble at the time of the operation, but recovered favourably, and was discharged cured, Sept. 16.

20. Aug. 3. Mr. Quain removed a tumor from the front of the tibia of Sarah Howell, aged 19. Made out-patient, Sept. 8.

21. Aug. 11. Mr. Morton operated for stone in the bladder, on Mary Ann M——, aged 35.

"This patient was admitted 17th July, 1847; married six years, and of good constitution. Soon after a natural labour, two years and a half ago, she began to experience pain and heat during micturition. As the symptoms increased she was sounded in the country, but no stone was detected. About a year ago, she miscarried in the fifth month of pregnancy. About this time she was again examined twice, but no stone was discovered, and the disease was regarded and treated as one affecting the coats of the bladder. About this time, also, the urine began to deposit much mucous and phosphatic sediment. It was also alkaline, and contained some

albumen and pus-globules. Mr. Morton examined her, and at once found a large rough stone. Aug. 11. She was placed under the influence of ether by Dr. Snow, a Weiss's three-branched dilator introduced into the urethra, and that canal dilated to its full extent. The cervix vesica was then notched, in the direction of the rami of the pubes, to a limited extent, and the forefinger introduced into the bladder, and the parts still further dilated. The forceps were then introduced, and a large rough stone extracted, the patient having been perfectly insensible throughout the operation. By Mr. Liston's advice a tube was introduced into the bladder, and allowed to remain for twenty-four hours. The stone weighed iv. drs. xii. grs. Its long diameter was an inch and three-quarters, its short diameter an inch and a quarter; the long circumference four inches, and the short one two inches and seven-eighths. Aug. 19. Hitherto she has had no incontinence of urine, and is quite well. Sept. 1. She left the hospital in good health, but she is not able to retain her urine so long as formerly, though this varies, as on some days she can do so for five hours at a time, whilst at other times she passes it every quarter of an hour."

22. August 30. Mr. Liston dissected out a large tumor from the side of the face and neck of Thomas H——, aged 66. It dipped behind the angle of the jaw, and had been operated on before. The wound healed chiefly by the first intention.

23. Sept. 8. Mr. Liston performed lithotomy on Benjamin Bonsey, aged 76. The stone was about two inches in its long diameter. Sept. 16. Going on well to this time.

It is very evident, that in none of the six cases that ended fatally, out of the foregoing two lists, can the event have been caused, or in any degree promoted, by the inhalation of ether, since there are very sufficient and well-recognised causes to account for the result.

The case of Stanton, No. 42 in the first list, is particularly illustrative of the great safety of ether under proper management, in cases which might be presumed to be the most unfavourable for its use. The disease of the heart in this man was very great, and etherization was carried to its full extent, and complete insensibility kept up for a quarter of an hour, yet not the least ill effect resulted from it; he completely recovered from the influence of the ether before he was removed from the operating table. The

patient—a bad subject for the operation, undertaken at his particular request—was attacked with phagedenic ulceration, and died in one of the cold fits of the fever attending it; the strength of the heart being apparently insufficient to establish re-action.

The following Tables shew the result of the larger operations. One case of lithotomy is not included; as, although the patient is going on favourably, time enough has not yet transpired for the result to be declared.

1. St. George's Hospital.

| Operations | | No. of Cases | Recoveries | Deaths |
|---|---|---|---|---|
| Amputations | Thigh .... | 11 | 9 | 2 |
| | Leg .... | 7 | 6 | 1 |
| | Arm .... | 1 | 1 | 0 |
| | Fore-arm .. | 2 | 2 | 0 |
| | Total .. | 21 | 18 | 3 |
| Lithotomy.. | | 2 | 2 | 0 |

2. University College Hospital.

| Operations | | No. of Cases | Recoveries | Deaths |
|---|---|---|---|---|
| Amputations | Thigh ..... | 3 | 3 | 0 |
| | Leg .... | 1 | 0 | 1 |
| | Arm .... | 1 | 0 | 1 |
| | Total .. | 5 | 3 | 2 |
| Lithotomy.. | | 3 | 3 | 0 |

3. BOTH HOSPITALS COMBINED.

| Operations | | No. of Cases | Recoveries | Deaths |
|---|---|---|---|---|
| Amputations | Thigh .... | 14 | 12 | 2 |
| | Leg .... | 8 | 6 | 2 |
| | Arm .... | 2 | 1 | 1 |
| | Fore-arm .. | 2 | 2 | 0 |
| | Total .. | 26 | 21 | 5 |
| Lithotomy.. | | 5 | 5 | 0 |

The first Table includes the two amputations in which Mr. Bumpsted administered the ether, and it comprises, I believe, all the amputations at St. George's Hospital since January 28, except one—an amputation of the leg after an injury, which was performed without ether, and I think in the night-time—(the patient recovered). The deaths after all the twenty-six amputations, as shown in the third Table, are five, which is a little below 20 per cent. This is lower than the average mortality after the removal of diseased limbs; Dr. Lawrie's return of the Glasgow Infirmary, for instance, giving 24 per cent. (The mortality after amputations on account of injuries was 54 per cent in his return.) The five cases of lithotomy all ended in recovery. There were six operations on the female breast at St. George's Hospital, in which the whole gland was removed, and the patients all recovered from the operation. Finally, after the fifty-six operations in this hospital, there were but four deaths; and after twenty-two operations in University College Hospital, but two deaths. Although this number of operations is not large enough to determine a question of this kind, yet it must be admitted that the results are so

far very satisfactory, and tend to confirm the expectation which we might reasonably entertain beforehand, respecting the influence of ether over the patients' recovery.

## APPENDIX

*The Notes refer to the Numbers in parentheses in the Text.*

### NOTE (1), p. 61.

THE circulation of the blood continues for a little time in animals after the respiration has been arrested by the influence of ether, and it ceases, apparently, from want of respiration, and not from the direct effects of the ether. This I observed early in the year, but it was first made known by the Parisian physiologists. The reason of this, I believe, is not that ether is incapable of paralyzing the heart and blood-vessels, but that it sooner affects the medulla oblongata, and the nerves connected with it, than the ganglionic nervous system. Indeed, I have ascertained that such is the case, from observations I have made on frogs. If placed in air containing but 20 or 30 per cent of vapour of ether, they very quickly become affected, probably from the rapid absorption of the vapour by the skin: in a minute or two the respiration ceases, and they have every appearance of being dead, except that the heart can be seen pulsating on the under side of the chest. If they are now withdrawn, the circulation continues, the ether gradually evaporates by the skin, and respiration recommences, in a period varying from 5 to 15 minutes, according to the length of the previous exposure to the vapour: whilst, on the other hand, if they are allowed to remain in the air containing vapour, more ether continues to be absorbed, and in about five minutes the heart ceases to beat perceptibly, although its pulsations would continue for hours without the respiration, even in a frog immersed

in water that has been deprived of its air by boiling. Some slight vermicular contractions of the heart, that would be visible on dissection, continue for a little time, and if the frogs are withdrawn from the vapour during this interval, and kept moist, they may yet recover, although they sometimes show no signs of life for an hour and a half.

Although etherization and asphyxia resemble each other in some respects, yet the rapidity with which frogs are affected with ether, whilst they are so very slowly asphyxiated by privation of air, proves that they differ widely, and shows clearly enough that the effects of the vapour of ether are not due to its excluding part of the oxygen of the air by the space it occupies, as might at first, perhaps, be supposed. That such is not the way in which ether acts I ascertained in a more direct way in the beginning of the year, by supplying artificially the oxygen so displaced, when I found that the peculiar effects of ether were produced in animals just as readily as before. If hydrogen, nitrogen, or any neutral gas which does not support life, were mixed with the air, in even half the quantity that vapour of ether is commonly mixed with it, the oxygen of the air, over-diluted, would fail to be imbibed into the blood in exchange for carbonic acid, and the patient would suffer asphyxia, the blood being arrested in its passage through the pulmonary capillaries. The oxygen is often reduced by the vapour of ether to 10 or 11 per cent. of what the patient breathes, whilst if it were reduced but to 16 per cent. by a gas which is not absorbed, no increased efforts of respiration would prevent asphyxia from quickly supervening.* That nothing of the kind takes place during the inhalation of ether depends on the circumstance that the vapour is absorbed as fast as it reaches the air-cells of

* See a paper "On the Pathological Effects of Atmospheres vitiated by Carbonic Acid Gas, and by a Diminution of the due Proportion of Oxygen."—*Edin. Med. Surg. Journ.*, Jan. 1846.

the lungs, leaving the oxygen in its usual proportion per cent.; and to get enough of it the patient usually enlarges his respiratory movements instinctively, as he would do if situated on a high mountain, where the air is much rarefied.

NOTE (2), p. 63.

When air is admitted to a liquid containing ether, the liquid parts with some of its ether to the air; whilst, if air containing ether is admitted to a liquid containing none, it parts with some of its ether to the liquid; and in either case a balance is established. The interposition of a thin animal membrane between the liquid and air, like that between the blood and the air in the lungs, does not interrupt this interchange. The quantity of ether that a limited portion of air will withdraw in the form of vapour, from a liquid containing it, is determined by the temperature and the quantity in the liquid: for instance, if the liquid is saturated with ether, the air will become saturated also, for that particular temperature; if the liquid is half saturated, the air can only withdraw as much as will half saturate it; and so on, in a direct ratio, as I have ascertained by experiments. It is not improbable that some of the ether inhaled is decomposed in the body; but this does not alter the question of de-etherization in this manner, for assuredly by far the greater proportion of the ether escapes by the breath unaltered.

Ether exists in the blood during etherization as a liquid, not as vapour. Although the temperature of the blood is a little higher than the boiling point of ether, yet it is capable of absorbing the vapour readily, and holding it in solution. 100 parts of water at 60° will hold in solution about 10 parts of ether, or rather more than 23 times their own volume of the vapour: at 100°—the temperature of the blood —water will absorb and hold in solution about half the

above quantity, and it is capable of absorbing the vapour of ether, and holding it dissolved at all temperatures up to 212°, its own boiling point, but in a constantly diminishing quantity. Blood, on account of its density, absorbs less ether than water at corresponding temperatures; but it is capable of absorbing more than it has ever the opportunity of doing in the process of etherization.

NOTE (3), p. 169.

The quantity of water contained in washed ether is more than sufficient to saturate the driest air at any temperature at which it can be breathed; and that it does rise in vapour along with the ether, may be experimentally ascertained, by attaching two tubes containing chloride of calcium to an inhaler, or a Wolf's bottle, in which there is some ether, washed and not deprived of the water, and then passing air over the whole; when it will be found that the air, after parting with all its moisture to the chloride of calcium in the first tube, takes up water again along with the ether, and gives it up to the chloride in the second tube, in quantity increasing with the temperature.

NOTE (4), p. 256.

The size of the patient is the only circumstance which I have observed constantly to influence the quantity of ether required to produce insensibility, when the inhalation goes on steadily; if the inhalation is interrupted, however, more ether is used, as the process has to commence, in some measure, afresh. The man who was the subject of excision of the elbow-joint by Mr. Liston, in University College Hospital, might seem an exception to this. The ether was finished soon after the operation began, although ℥ij. had been put into the inhaler; I found afterwards, however, that it had not been all inhaled, but that a great

part of it (owing to an irregularity in the volute of the inhaler I was using, by which the passage for air was much contracted at one place), had been splashed into the elastic tube, whilst the patient was breathing deeply and forcibly. Females generally consume less ether than males, but then they are usually of less stature and weight. Hard drinkers do *not* appear to require more ether than others, and are not more difficult to render insensible. The time occupied in producing complete insensibility varies with the activity and depth of the respiration; but it seldom exceeds two to three minutes in a child, or four to six minutes in an adult, when the inhalation is not interrupted; unless the vapour gets diluted to a greater extent, by the valve being kept open, or the face-piece not fitting, or by some other means.

NOTE (5), p. 260.

There is no difficulty in distinguishing voluntary motion from excito-motory movements, or the rhythmic automatic ones, in a patient who is unconscious of what is occurring around. Voluntary motion is recognized as such at once, even in an animalcule under the microscope, but much more readily in one's own species. Both sensation and voluntary motion may exist in the second degree of etherization without consciousness, as in natural sleep, when a person feels the heat or the cold, and pushes off the coverlet, or folds it closer round him, according to circumstances, without waking; consequently, the assertion of the patient that he has had no pain is not to be considered a proof that there has been none, in cases where there have been unequivocal demonstrations of it. On the other hand, every little struggle or moan must not be considered a proof of pain, since it may be independent of the operation, or merely excito-motory, or the result of very obscure sensation. And when cries expressive of pain do

occur, they must not be taken as a measure of the pain, for when the patient is unconscious he is not using the slightest self-control. There is no room for an opinion that the patients generally have pain, and are unconscious or oblivious of it; for when the ether is well administered, there is generally no expression of any kind by the features or voice, and a number of patients recover their mental faculties and special senses, whilst the sensibility is still so far blunted that the minor parts of an operation cause no pain.

NOTE (6), p. 350.

Dr. Pring, of Weston-super-Mare, found (as he stated in the Lancet, May 1st), that ether will render arterial blood dark-coloured, and impair its coagulation out of the body; but a much larger quantity of ether was no doubt introduced than enters the blood during inhalation.

NOTE (7), p. 356.

The method of giving ether with no other appliance than a sponge placed over the mouth and nostrils, which was introduced by Dr. Smith, of Cheltenham, is one that will succeed in causing insensibility; and this is a happy circumstance that will extend the use of ether to many cases of emergency, in which otherwise the patients might be deprived of its benefits. In the cases of infants it is perhaps the best way of exhibiting ether, but for children of two years of age and upwards I have a small face-piece, and prefer to use the inhaler. The simple sponge is preferable, for all cases, to many of the apparatuses which were in use, and Dr. Morton, of Boston, U.S. (as appears by a communication he sent to the Lancet), uses it in preference to the inhaler he at first employed; but I cannot admit that it is equal to a good apparatus. It is an expensive means,

as not one-half of the ether which is dissipated enters either the mouth or nostrils of the patient; and it is a means which does not admit of any kind of regulation as regards the strength of the vapour.

In large operations on the face, like that described at page 355, the administration of the vapour of ether per rectum—the method of Prof. Pirogoff, of St. Petersburgh —would certainly be better than inhalation, if it is equally safe and manageable. The Professor, (I think I have read so), has removed the superior maxillary bone, under the influence of ether exhibited in this way. He recommends this plan, indeed, in all cases, as preferable to inhalation, on account of certain disadvantages and discomforts which he considers attend the latter; but, in all probability, he has not seen inhalation practised with a good apparatus, and I have not had sufficient experience of his method to be able to speak of its merits.

THE END

*NEW INVENTIONS*

# A PORTABLE OXYGEN ANALYSER

By A. BRACKEN

*Research and Development Department,*
*The British Oxygen Company, Limited*

IT is frequently desirable to be able to determine the oxygen concentration in a gas mixture using a rapid, simple method of analysis not dependent on caustic or corrosive absorbent solutions. Investigations involving oxygen tents of various kinds, certain physiological experiments and some problems in anæsthesia are typical cases. A slight loss of accuracy compared with the standard Haldane apparatus could be tolerated, provided the other advantages of convenience and rapidity were present. A few prototypes of a suitable instrument, which is also compact and portable, have now been produced and a recent article by Burns (Burns and Hall, 1953) and his colleagues at Guy's Hospital illustrates some of the uses to which one of the prototypes has been put in a large London Hospital. The analyser used was based on one developed in America during the war (Wood and Shoemaker, 1944), but the actual instrument was made in Britain.

## GENERAL DESCRIPTION

The instrument (fig. 1) is housed in a small, light box, part of the front of which is in the form of a translucent calibrated scale. This is illuminated by a spot of light on depressing a switch on the top of the case. A rubber bulb and drying tube are mounted on the back of the box, and

they are connected to the inside of the instrument by small-bore rubber tubing. A second, longer length of small-bore rubber tubing leads from the inside of the instrument to the test atmosphere.

The rubber bulb is fitted with a small uni-directional valve, so arranged that on compression of the bulb the air in it is passed out to waste. When the bulb expands the atmosphere inside the instrument is drawn into the bulb. On repeating these compressions and expansions several times during about one minute, the test atmosphere is drawn through the instrument and finally replaces completely the air or other gas mixture originally present. On depressing the switch the spot of light on the scale indicates at once the percentage of oxygen in the sample.

The instrument used covers the range 0 per cent to 100 per cent oxygen with an accuracy of ± 2 per cent absolute, at normal temperatures and pressures. A suitable correction would be required for readings taken at widely different temperatures or pressures.

## SCIENTIFIC BASIS OF INSTRUMENT

The instrument depends upon what has come to be known as the Pauling principle (Pauling, 1941) which utilizes the fact that oxygen is the only common gas with pronounced magnetic properties. Its volume susceptibility is $+151 \times 10^{-9}$ c.g.s. electromagnetic units. As a contrast, the figure for nitrogen is only $-0.43 \times 10^{-9}$ c.g.s. electromagnetic units. No gases or vapours normally used in anæsthesia or physiological work (nitrous oxide, carbon dioxide, carbon monoxide, helium, cyclopropane, ether vapour and trichlorethylene vapour) have magnetic properties comparable with those of oxygen. The only gases which are paramagnetic like oxygen and might conceivably interfere with

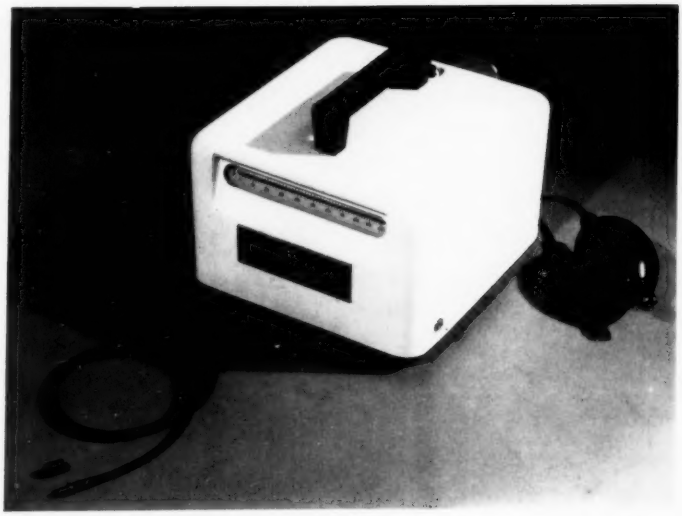

FIG. 1
Oxygen Analyser

an analytical procedure based on this property are nitric oxide and chlorine dioxide.

If a test body, such as a glass sphere, is placed in the magnetic field lying between two large flat pole pieces of a magnet, it will not be subjected to any force because the magnetic field is uniform. If the same body is placed in a non-uniform field, for example to one side of the centre line between two wedge-shaped pole pieces, then it will be acted upon by a force whose magnitude depends upon two factors. These are: (*a*) that dependent upon the magnetic properties of the test body and the magnetic system, producing forces which would be exerted even in a vacuum; and (*b*) that which results from the displacement of the medium by the test body. The effect of the first forces is a constant for the system; that of the second depends upon the magnetic susceptibility of the gases present. If oxygen forms a significant part of these gases, then the resultant force acting on the test body will vary with the oxygen content. Conversely, the magnitude of the force may be measured, and this measurement used as the analytical method for determining the partial pressure of oxygen in the gas mixture.

In the instrument used here, two hollow glass, nitrogen-filled spheres are joined by a glass rod and the resulting dumb-bell, which weighs only eight milligrams, is cemented at right angles across a vertical thin quartz fibre. A small diamond-shaped mirror is also fixed to the fibre. Two magnets are used, so that there are four pole pieces, and they are arranged so that the forces acting upon the spheres reinforce each other. A twisting force is thus exerted upon the fibre and the dumb-bell rotates into an equilibrium position. This position depends upon the partial pressure of the oxygen in the surrounding medium, and the restoring force exerted by the quartz fibre.

A light source within the outer case, operating from two small dry batteries, is focused on the mirror and the spot of light is reflected back upon the scale. The position of the light spot indicates the oxygen concentration in the sample. On introducing a different gas mixture the equilibrium position of the dumb-bell is disturbed, owing to the different magnetic susceptibility of the new sample. The fibre, dumb-bell and mirror take up a different position and the beam of light illuminates another point on the scale.

The instrument is set up in air giving a reference point corresponding to 21 per cent oxygen, and the two other reference points are obtained by replacing the air by nitrogen (0 per cent oxygen) and by 100 per cent oxygen. These points fix the length of the scale and intermediate points are obtained by direct calibration using known oxygen mixtures.

## THE DRYING AGENT

Self-indicating silica gel was found to be the most satisfactory agent in the drying tube. This material is blue when dry and pink when moist. However, it was found that silica gel absorbs ether vapour, so, for use in anæsthetic circuits where ether was present, the silica gel was replaced by a dried cotton yarn which was rendered self-indicating in a similar manner to the silica gel. The yarn had not quite the activity of silica gel but its absorptive power was selective for water vapour, and it could be regenerated by simple heating (140° C. for two hours) in a hot air oven.

## GENERAL COMMENTS

The quartz fibre suspension was fragile and the unit was supported on sponge rubber. The outer case was also supported on rubber feet. In using the instrument no excessive precautions against breakage were necessary and

it was completely portable. It was found to be necessary to stand it on a firm level surface when taking readings. The replaceable items were the dry batteries (of a standard pattern) and the drying agent. Apart from these occasional replacements, no maintenance was necessary.

Several of the instruments have been successfully produced but they are still in the research stage and are not yet ready for quantity production.

REFERENCES

Wood, R. E., and Shoemaker, D. P. (1944). Division II, National Defense Research Committee of the Office of Scientific Research and Development, Report No. 4361.

Pauling, L. (1941). (California Institute Research Foundation.) U.S. Patent No. 2,416,344.

Burns, T. H. S., and Hall, G. M. (1953). *Brit. med. J.* (In the press.)

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## AN ATTACHMENT TO ALLOW A STOMACH TUBE TO BE USED WITH A FACE PIECE

By J. CLUTTON-BROCK

*Selly Oak Hospital, Birmingham*

I HAVE previously described a technique for anæsthetizing the curarized patient (Clutton-Brock, 1949). With this technique a thin rubber diaphragm, attached by rubber solution to a face piece, covers a three-quarter inch diameter hole in that part of the face piece which lies over the patient's mouth. The proximal end of a large stomach tube, passed on the curarized and anæsthetized patient, comes through a small hole in the diaphragm, stretching the rubber to accommodate it. Thus the airtight fit of the face piece is maintained. An ordinary airway is used beside the stomach tube.

The attachment illustrated (fig. 2) was designed for me by Mr. A. C. King. It allows the thin rubber diaphragm, contained within it, to be attached securely to the face piece and to be changed readily. There is a stopper on a chain to allow the face piece to be used when a stomach tube is not necessary.

I have now used the technique described extensively for over four years without mishap and use a cuffed endotracheal tube only when it is particularly likely that the stomach may have much in it, or its contents be expressed by surgical manipulations, as for example in intestinal obstruction or gastric surgery, or where it is difficult to keep an airtight fit with a face piece.

Difficulties in keeping a patent airway seem to occur much less frequently if there is a stomach tube in position, presumably it tends to hold the tongue forward, leaving an airway on either side of it.

The technique was originally designed for patients in Trendelenburg position, but I am now convinced that a large stomach tube is essential for all curarized patients if a cuffed endotracheal tube is not used.

For adults I use a thirty-inch long 20 or 22 English gauge rectal type tube, with three extra side holes cut in the distal six inches. I think that the terminal hole in this type of tube is an added safeguard against blockage. If the proximal end of the tube is cut on the slant it can easily be passed through the hole in the diaphragm without the use of forceps.

The tube prevents the stomach being inflated with anæsthetic gases, when artificial respiration is being performed and prevents stomach contents coming into the pharynx. The stomach tube is particularly important when neostigmine has been given, as this drug frequently causes

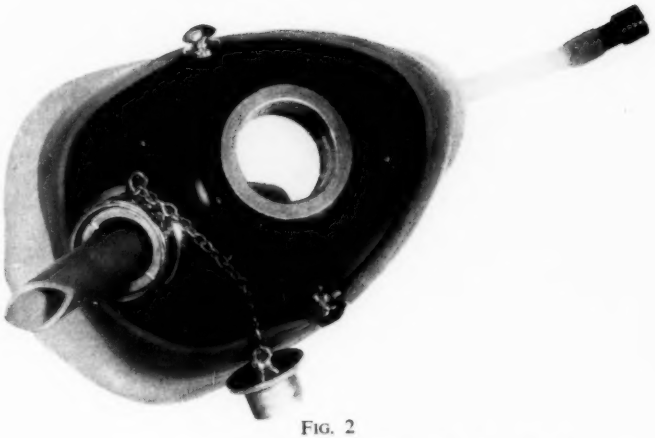

FIG. 2

An attachment to allow a stomach tube to be used with a face-piece.

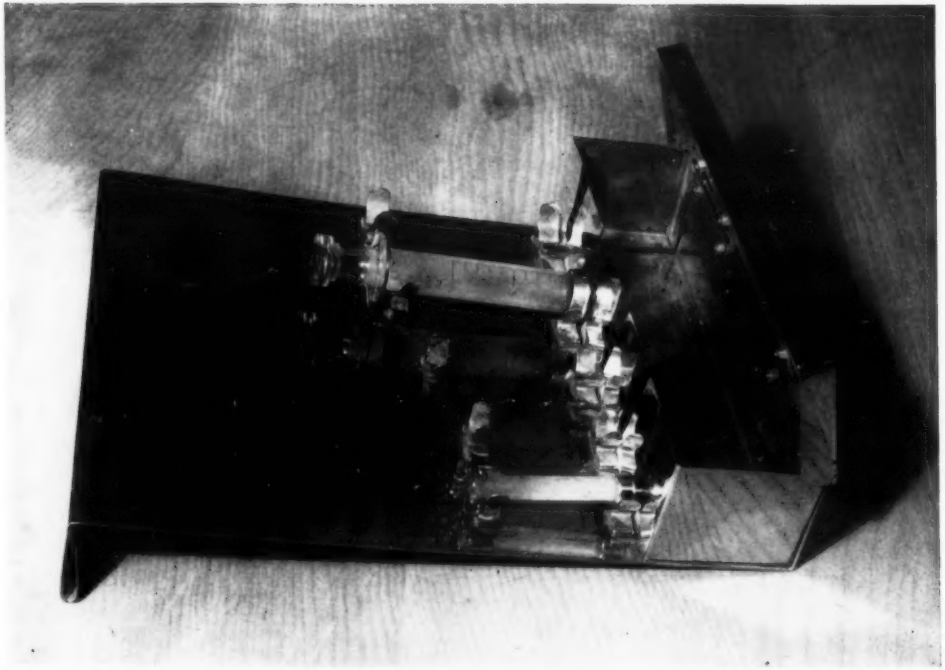

FIG. 3
The " Whittington " Syringe Stand

powerful gastric contractions. The tube should be left in place until the patient regains adequate reflex control.

A small metal can, such as is used to warm ether bottles, can be hung on the face piece to catch the stomach contents issuing from the tube.

The attachment is obtainable from Messrs. A. C. King, 27 Devonshire Street, London, W.1.

REFERENCE

Clutton-Brock, J. (1949). *Anæsthesia*, **4**, 141.

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## THE "WHITTINGTON" SYRINGE STAND

By O. H. Belam and David Zuck

*Department of Anæsthetics, Whittington Hospital, London*

THIS syringe stand (fig. 3) is designed to protect intravenous needles from contamination when used for repeated injections during an operation. The stand is sterilized by boiling, and the syringes rest upon spring supports with the needles suspended in a closed, sterile compartment.

Labelled spring clips are used for identification of syringes, although in this hospital certain sizes of syringe are invariably used for certain drugs, e.g. 20 ml. syringes for thiopentone, 5 ml. syringes for tubocurarine, and so on.

The stand has been produced for us by A. Charles King Ltd., 27 Devonshire Street, W.1.

## REVIEWS

*Extrasystoles and Allied Arrhythmias.* By David Scherf and Adolph Schott. Published by Wm. Heinemann, Medical Books, Ltd. Pp. 531. 213 illustrations. Price £5 5*s*. 0*d*.

The development of the cardiological aspects of anæsthesia has received impetus from the widespread adoption of anæsthetic and surgical procedures which may profoundly influence heart action. Hitherto, the literature on the subject has been scattered throughout journals and periodicals, the multiplicity of which rendered difficult and tedious the search for information. This book, with its wealth of illustration and reference, provides the most comprehensive account of the various disturbances of cardiac rhythm which may be encountered in experimental or clinical practice.

In the introductory remarks the terminology relating to cardiac arrhythmia is rationalized. The term "extrasystole" is preferred for the clinically common disturbance due to contractions caused by impulses which interfere with, or replace, the dominant rhythm and which are accurately coupled to the preceding beat. Other descriptions such as "premature", "ectopic", "heterotopic", "idioventricular" or "automatic" are reserved for more specific use.

The subject matter, though divided into twelve chapters, falls roughly into two main sections. The first section opens with a description of the historical aspects of pulse irregularities from Galen to Einthoven, followed by a most detailed account of the extrasystolic disturbances, pararrhythmias, fibrillation, and paroxysmal tachycardias. The section is liberally illustrated with cardiograms and the

subtle differences between extrasystole and parasystole are well explained.

The second section deals mainly with the ætiology of the arrhythmias, and the different mechanisms underlying their production. These chapters make difficult reading and serve to illustrate the confusion of opinions which exists regarding the significance and causes of irregularities. A review of most of the experimental and clinical work on the effects of anæsthetics on the heart is included in this section. It is regrettable that no reference was made to John Snow's work on cardiac syncope, a work, which, after almost one hundred years, remains a model of accurate observation and intelligent surmise; the authors did not hesitate to criticize Prinzmetal's failure to refer to their earlier papers on auricular fibrillation.

The account of Levy's investigations is not fully accurate. Levy observed that vagotomy, or atropinization, increased the tendency to ventricular tachycardia and ventricular fibrillation during chloroform anæsthesia, and not the contrary, as the authors state. Their views on the effect of atropine on cardiac irregularities cannot be accepted unreservedly. Admittedly, atropine will abolish a "functional" bradycardia or an irregularity which is due to an A-V dissociation with interference, but there exists much evidence to show that, under certain circumstances, it may precipitate severe extrasystolic or fibrillary disturbances.

The chapters describing the mechanisms and the physiological aspects of the arrhythmias are thorough and informative. The authors deserve congratulations for attempting to stimulate interest "amongst those who are engaged in the study of physiological and clinical problems which centre round the initiation and propagation of the impulses". It is in this respect that the anæsthetist, by

careful study of heart action during anæsthesia, may be able to throw some light on a subject that has created so many conflicting opinions.

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*The Medical Annual* 1953. Edited by Sir Henry Tidy and Dr. Rendle Short. Published by John Wright and Sons Ltd., Bristol. Pp. 532. 72 plates. Price 27*s.* 6*d.*

*The Medical Annual* for 1953, slightly larger than last year's, is chiefly remarkable for the re-designed green cloth binding and an article on medicine in the reign of Elizabeth I. As regards the section on anæsthetics, Dr. Langton Hewer calls attention to the increased realization of the dangers of controlled hypotension with methonium drugs, mentioning a formidable list of non-fatal complications, including hæmorrhage, hemiplegia, paraplegia and blindness.

A general review of what is new and important is given in the introduction, and the appropriate article indicated in which more detailed information may be found. The index of pharmaceutical preparations and surgical appliances at the end should prove useful. The book is as usual very good value for money.

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*Technic* (Journal of the Association of Operating Theatre Technicians), Vol. 1, No. 1. Published bi-monthly by Wise and Co. (Printers) Ltd. Price 2*s.* 6*d.*

It is with particular pleasure that we welcome this periodical. The *British Journal of Anæsthesia* has always had the interests of the Association of Operating Theatre Technicians very much at heart, and has deprecated the slow advancement in their recognition since our Editorial in April 1950. *Technic* should do much to improve their prestige, and is an astonishing tribute to the drive and

energy of the officers of the Association who are prepared to initiate such an enterprise, when times for publishing are so difficult.

In this journal will be found, in addition to an encouraging Foreword from the Chairman, Alderman S. A. Elson, who has over 35 years in hospital service, a critical assessment of the present-day position of bromethol by Dr. George Edwards, noticeable particularly for a new horror, "Avertinization"; a brief account of the Course for Theatre Technicians which is organized at the Birmingham Accident Hospital; news of the Association; and much lighter fare, varying from sport to modern hair styles of today. Of special interest to anæsthetists will be the account which is given of the negotiations for recognition of the Association by the Board of Registration for Medical Auxiliaries.

It would appear, from the announcement of a Board of Examiners, that the first examination for Theatre Technicians will be held in October. This is to include three surgical questions, two questions set by anæsthetists, and two questions on bacteriology. The institution of this examination is a necessary step for the essential recognition of these tremendously useful assistants as Medical Auxiliaries.

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*Excerpta Medica: Cancer (Experimental and Clinical)*, Section xvi, Vol. 1, No. 1, July 1953.

Such is the volume of writing on the subject of cancer that it is surprising to find that it is only in July 1953 that the first number of the first volume of this section of the *Excerpta Medica* has been issued. Enormous as the work must be in collecting this mass of writing, the sifting of the wheat from the chaff calls for a nice discrimination that is at least as exacting. We may hope that in the course of time the saying that " In the multitude of counsellors there

is safety" may once again prove true. Unfortunately that time is not yet, but it may be that the publication of the cancer section of the *Excerpta Medica*, which looks at the subject from so many different angles, may contain that avenue which leads to the truth, the truth that frees humanity from the terrible scourge of cancer.

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## FACULTY OF ANÆSTHETISTS

The following have been appointed as Examiners for the Fellowship of the Faculty of Anæsthetists of the Royal College of Surgeons of England for the ensuing year:

PRIMARY EXAMINATION

| | |
|---|---|
| *Anatomy* | Professor Gilbert Causey<br>Professor J. Whillis |
| *Physiology* | Professor David Slome<br>Professor W. R. Spurrell |
| *Pharmacology* | Professor C. A. Keele<br>Professor H. C. Stewart |
| *Pathology* | Professor G. Hadfield<br>Professor George Lumb |

FINAL EXAMINATION

| | |
|---|---|
| *Surgery* | Mr. A. Hedley Whyte |
| *Medicine* | Professor Alan Kekwick |
| *Anæsthetics* | Dr. Frankis T. Evans<br>Dr. T. Cecil Gray<br>Professor R. R. Macintosh<br>Mr. A. D. Marston<br>Dr. B. L. S. Murtagh<br>Dr. W. W. Mushin<br>Dr. G. S. W. Organe<br>Professor E. A. Pask |

The following have been appointed by the Conjoint Board as Examiners for the Diploma in Anæsthetics for the ensuing year:

| | |
|---|---|
| *In Anæsthesia* | Dr. W. A. Low |
| *In Surgery* | Mr. C. E. Shattock |

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† = Book Review

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